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Sweet taste modulates social-affective processing: Elevated explicit affective ratings and attenuated LPP differentiation

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Sweet taste modulates social-affective processing: Elevated explicit affective ratings and attenuated LPP differentiation

Abstract

Sweet taste is associated with positive affect and interpersonal intimacy, but its influence on social-affective processing remains unclear. Across two ERP experiments, we examined how sweetness modulates explicit affective evaluations and late positive potential (LPP) differentiation of social information in heterosexual women. In Experiment 1 (N = 32), participants evaluated romantic and friendship interaction pictures under sweet and control taste conditions. Sweetness increased overall valence and arousal ratings and attenuated romantic–friendship LPP differentiation, with a significant Taste × Picture Type interaction (η_p^2 = .139). In Experiment 2 (N = 56), participants passively viewed positive, negative, and neutral opposite-sex interaction pictures in either a sweet or control group. A significant Group × Picture Type interaction (η_p^2 = .060) was observed, with smaller positive–neutral and positive–negative LPP differentiation in the sweet group than in the control group, as confirmed by Holm-corrected interaction contrasts. Together, these findings suggest that sweet taste modulates explicit affective evaluation and late-stage electrophysiological differentiation in distinct ways.

Keywords: sweet taste; social-affective processing; embodied cognition; ERPs; LPP

Introduction

Embodied cognition theory proposes that social cognition can be influenced by bodily and sensory experiences (Barsalou, 2020; Shapiro, 2007). One possible basis for such cross-

modal influences is shared affective meaning: stimuli with similar emotional qualities may become associated across domains (Spence, 2020). Taste is particularly relevant in this context because gustatory experiences have been linked to affective states and social judgments (Meier et al., 2017; Huang et al., 2025). Among different taste qualities, sweetness is typically associated with positive hedonic value (Rolls, 2015) and has also been linked to broader affective and interpersonal meanings. These associations are evident both in early positive responses to sweet tastes (Mennella & Bobowski, 2015) and in the widespread use of sweetness-related metaphors to describe positive interpersonal and romantic experiences in adulthood (Meier et al., 2012; Ren et al., 2015; Zhou & Tse, 2020). These findings provide a basis for examining whether sweet taste can influence the processing of intimacy-related social information.

Previous studies suggest that sweet taste can influence several aspects of social cognition. At the behavioral level, sweet taste has been linked to greater prosocial intentions and behavior (Meier et al., 2012; Schaefer et al., 2021, 2023). Electrophysiological evidence has further suggested that sweet taste can influence romantic semantic processing (Wang et al., 2019). However, it remains unclear whether these effects extend beyond semantic materials to visually presented interpersonal interactions and how sweetness modulates explicit affective evaluations and electrophysiological responses to such social information. One possibility is a reward-enhancement account. Sweet taste constitutes a primary sensory reward and is associated with positive hedonic value (Berridge & Kringelbach, 2015; Rolls, 2023). Experiencing sweetness may therefore provide a positive affective context that increases the

motivational significance of subsequently presented positive social information. According to motivated-attention accounts, emotionally and motivationally salient stimuli receive prioritized attentional allocation and more sustained elaborative processing (Schupp et al., 2006). From this perspective, sweet taste could enhance both explicit affective evaluations and the later sustained processing of positive or romantically salient social stimuli.

Conversely, a reward-competition account predicts that sweet-taste stimulation may attenuate the relative processing advantage of subsequently presented positive social information. Primary rewards such as sweet taste and secondary rewards such as positive social cues can engage partially overlapping valuation-related systems (Levy & Glimcher, 2012; Ruff & Fehr, 2014; Sescousse et al., 2013). More broadly, motivational responses to a subsequent rewarding event may depend on the organism's current affective and motivational state. Reward responsiveness can vary with internal physiological states and satiation. Theoretical work has described how homeostatic needs influence reward-directed behavior (Keramati & Gutkin, 2014), while neuroimaging studies have documented changes in reward-related neural responses following satiation (O'Doherty et al., 2000; Kringelbach et al., 2003; Thomas et al., 2015). These findings raise the question of whether sweet-taste stimulation may similarly influence the allocation of sustained processing resources to subsequently presented positive social information. If so, the relative late-stage processing advantage of positive or romantically salient stimuli should be attenuated under sweetness.

These two perspectives offer contrasting predictions regarding the late-stage neural processing of social information. Event-related potentials (ERPs) provide the temporal resolution needed to examine these predictions (Olofsson et al., 2008). In particular, the late

positive potential (LPP) is associated with sustained motivated attention and elaborative processing of emotionally or motivationally salient information, with larger amplitudes generally reflecting greater sustained processing (Cuthbert et al., 2000; Hajcak et al., 2010). The LPP therefore provides a suitable electrophysiological measure for examining how sweet taste influences the relative late-stage processing of different social stimulus categories.

To systematically test these hypotheses, the present study conducted two complementary ERP experiments. Experiment 1 first examined whether sweet taste modulates the processing of romantic interactions relative to friendship interactions. At the behavioral level, we expected sweet taste to shift explicit affective evaluations toward greater positivity and arousal. At the electrophysiological level, we tested two alternative predictions. The reward-enhancement account predicts that sweetness should strengthen LPP differentiation between romantic and friendship stimuli, particularly by increasing the relative processing advantage of romantic stimuli. In contrast, the reward-competition account predicts that sweetness should attenuate this category-related LPP differentiation. Experiment 2 extended this question by using a passive-viewing paradigm and by dividing opposite-sex interaction pictures into positive, negative, and neutral categories, allowing us to examine whether the late-stage modulation generalized to a context without trial-by-trial explicit evaluation and varied as a function of emotional valence. Positive pictures served as the focal condition because they contained relatively positive and affiliative social content, whereas negative and neutral pictures served as comparison conditions. Under the reward-enhancement account, sweetness should strengthen the late-stage LPP differentiation of positive pictures relative to the comparison conditions. Under the reward-competition account, however, this relative

differentiation should be attenuated under sweetness.

In summary, the present study aimed to determine whether sweet taste enhances or attenuates the late-stage differentiation of intimacy-related social information, thereby further clarifying cross-modal interactions between sweet taste and social-affective processing.

Experiment 1

Method

Participants

A total of 39 heterosexual female participants were initially recruited for this study. During data preprocessing, 7 participants were excluded because of excessive EEG artifacts, yielding a final sample of 32 participants for analysis. All participants were undergraduate or graduate students who were not majoring in psychology. They were right-handed, had normal or corrected-to-normal vision, reported no olfactory or gustatory impairments, and had no history of major physical, psychiatric, or neurological disorders. During recruitment, participants self-identified as heterosexual on a screening questionnaire. The sample was restricted to heterosexual women because the visual stimuli primarily depicted opposite-sex romantic interactions, allowing the romantic content to be more consistently relevant to the target participant group. Restricting the sample to a relatively homogeneous group also reduced variability associated with participant sex and sexual orientation. Previous research has reported sex-related differences in gustatory perception and in affective responses to emotional visual stimuli (Bartoshuk et al., 1994; Bradley et al., 2001; Jiang & Chiang, 2023; Olofsson et al., 2008). Furthermore, an a priori power analysis was conducted using G*Power 3.1.9.7

software (Faul et al., 2007). Assuming a medium effect size ($f = 0.25$), a significance level of $\alpha = .05$, and statistical power of $1 - \beta = .80$, the analysis indicated that a minimum sample size of 24 participants was required to detect the within-subject Taste × Picture Type interaction in the 2 × 2 repeated-measures design. The final sample of 32 participants therefore exceeded the minimum required sample size. The study was approved by an institutional ethics review board. Written informed consent was obtained from all participants.

Gustatory materials

In accordance with previous research (Wang et al., 2019), crystallized rock sugar (sucrose) was used to induce sweetness, whereas white kidney beans served as a control stimulus. Rock sugar was selected based on three methodological considerations. First, liquid gustatory stimulation requires careful control of swallowing-related movements that may introduce artifacts into EEG recordings (Jacquin-Piques et al., 2016; Wilton et al., 2019). Solid sugar-based materials can gradually dissolve in saliva (Wolff et al., 2002). Therefore, following Wang et al. (2019), rock sugar was used to provide sweet-taste stimulation during the task without requiring repeated delivery of liquid solutions. Second, unlike some non-nutritive sweeteners that may produce a bitter aftertaste (Kuhn et al., 2004; Schiffman et al., 1995), sucrose is typically associated with a pleasant sweet taste and positive hedonic value (Rolls, 2015). Third, because intra-oral somatosensory stimulation may itself contribute to neural responses (Rolls, 2015), white kidney beans were selected as a nonsweet oral control intended to approximate the intra-oral tactile properties of rock sugar, consistent with previous research (Wang et al., 2019).

To further characterize the sensory properties of the two gustatory materials, an independent pilot test was conducted prior to the formal experiments. Twenty participants who did not take part in the main study evaluated rock sugar and white kidney beans in terms of perceived sweetness, oral tactile intensity, and hardness, using 10-point scales ranging from 0 to 9. Paired-samples t tests showed that rock sugar was rated as significantly sweeter than white kidney beans, $t(19) = 11.02$, $p < .001$, Cohen's $dz = 2.46$. The two materials did not significantly differ in oral tactile intensity, $t(19) = -1.90$, $p = .072$, Cohen's $dz = -0.43$, or hardness, $t(19) = -0.15$, $p = .881$, Cohen's $dz = -0.03$. Prior to each experimental block, participants rinsed their mouths with purified water and placed the corresponding gustatory material on the mid-tongue surface. They were instructed to minimize unnecessary intra-oral movements, although spontaneous swallowing was permitted. Immediately before the formal task, participants completed a manipulation check of perceived sweetness using a 10-point scale ranging from 0 (tasteless) to 9 (extremely sweet), after which they began the experimental block while maintaining the material in their mouths.

Picture materials

Regarding the visual stimuli, pictures depicting intimate interactions between opposite-sex couples were used as romantic stimuli, whereas pictures depicting positive interactions between two women were used as friendship stimuli. Taking into account factors such as feasibility and ecological validity, the images were collected from publicly accessible online sources. A total of 400 social-interaction images were initially selected, comprising 200 opposite-sex romantic pictures and 200 same-sex friendship pictures, with both categories depicting positive interpersonal interactions. Stimulus screening involved two independent

pilot-rating stages. In the first stage, 35 heterosexual female volunteers who did not participate in the formal experiment rated all 400 images on romanticity (1 = not at all romantic, 9 = extremely romantic) and interpersonal intimacy (1 = not at all intimate, 9 = extremely intimate), and additionally completed a forced-choice judgment of the perceived relationship category (romantic partners/couple, friends, family members, colleagues/acquaintances, or uncertain). Based on predefined criteria, romantic pictures were required to have a mean romanticity rating ≥ 6, a romantic-partner classification rate ≥ 80%, and a mean intimacy rating ≥ 5, whereas friendship pictures were required to have a mean romanticity rating ≤ 4, a friendship classification rate ≥ 80%, and a mean intimacy rating ≥ 5. This initial screening retained 92 romantic and 87 friendship candidate images. In the second stage, another independent sample of 32 heterosexual female volunteers rated the retained images on valence, arousal, degree of physical contact, and interpersonal distance using 9-point scales. From these candidate images, 48 pictures from each category were selected for the formal experiment, yielding a total of 96 images. Item-level comparisons confirmed that romantic pictures received substantially higher romanticity ratings (M = 7.05, SD = 0.60) than friendship pictures (M = 3.18, SD = 0.57), $t(94) = 32.30$, $p < .001$, Cohen's d = 6.59. The mean proportion of ratings classifying the images into their intended relationship category was 91.8% for romantic pictures and 92.9% for friendship pictures, with all selected images meeting or exceeding the predefined 80% criterion. The two picture categories did not significantly differ in interpersonal intimacy (M = 6.37, SD = 0.55 vs. M = 6.33, SD = 0.51), $t(94) = 0.38$, $p = .707$, d = 0.08, or in valence, arousal, physical contact, and interpersonal distance (all $ps \geq .068$, all $|ds| \leq 0.38$). No statistically significant

differences were detected across these potential confounding dimensions. All images were presented in color and were standardized in terms of size, resolution, luminance, and saturation.

Procedure

Participants entered a moderately lit, sound-attenuated laboratory, where the experimenter fitted them with an EEG electrode cap and instructed them to minimize unnecessary body movements and blinking during the experiment. Participants were seated approximately 0.6 meters away from a computer monitor (49 × 29 cm), and the entire experimental paradigm was programmed and presented using E-Prime 2.0 software. The experiment was divided into two blocks: a sweet condition (rock sugar) block and a control condition (white kidney bean) block. The order of the experimental blocks was counterbalanced across participants. The entire experiment comprised a total of 192 trials (each block consisted of 96 trials, with 48 pictures from each of the two categories presented randomly once per block). At the onset of each block, participants were required to place the corresponding gustatory material at a specific position on the tongue surface and immediately complete a gustatory manipulation check using a 10-point scale (0 = tasteless, 9 = extremely sweet). Following the completion of the manipulation check, participants commenced the picture viewing and rating trials within that block while maintaining the material in their mouths. Throughout the picture-viewing task, participants were instructed to continuously keep the assigned gustatory material in their mouths. Each piece of rock sugar was sized to last throughout the block; in rare cases where it dissolved completely, participants replaced it only during the self-paced rating screen between trials to avoid introducing movement artifacts into the EEG recording window. The procedure for a single trial was as follows: a black fixation cross was first presented in the center of the screen

for 500 ms, followed by the random presentation of an experimental picture for 1500 ms; immediately after picture offset, an evaluation interface appeared below, and participants were required to rate the valence (1 = extremely unpleasant, 9 = extremely pleasant) and arousal (1 = extremely calm, 9 = extremely excited) of the picture using 9-point scales; upon completion of the rating, a blank screen was presented for 1000 ms as the inter-trial interval. After completing the first block, a mandatory 5-minute washout period was implemented to reduce potential gustatory carryover between blocks. During this period, participants rinsed their mouths with warm purified water at least three times and proceeded to the next block only after reporting no residual taste.

EEG recording and preprocessing

Continuous EEG signals were recorded online using a 64-channel electrode cap extended from the international 10–20 system and a 64-channel Brain Products EEG recording system (Brain Products GmbH, Gilching, Germany). Horizontal (HEOG) and vertical (VEOG) electrooculograms were recorded using bipolar/external electrodes, with HEOG electrodes placed 1 cm lateral to the outer canthi of both eyes and the VEOG electrode positioned 1 cm directly below the right eye. Scalp-electrode impedances were monitored throughout the recording and targeted to remain below 5 kΩ, and the online sampling rate was set to 1000 Hz. Offline data preprocessing was performed using the EEGLAB toolbox implemented in MATLAB (Delorme & Makeig, 2004). The preprocessing pipeline included the following steps: (1) ocular channels (IO, HEOG, and VEOG) were removed, retaining 61 scalp channels; (2) continuous EEG data were band-pass filtered at 0.1–30 Hz using a second-order Butterworth IIR filter, along with a 50-Hz notch filter to remove line noise, while a separate copy was band-

pass filtered at 1–30 Hz to serve as the training set for independent component analysis (ICA); (3) bad segments were identified by visual inspection and removed from both datasets over the same time intervals; (4) channels showing persistently poor signal quality during visual inspection were temporarily removed prior to ICA; (5) the data rank of the ICA training set was verified, and the extended Infomax ICA algorithm was then applied; (6) the resulting ICA weights were applied back to the main dataset; (7) typical artifactual components (e.g., saccades and blinks) were identified and rejected using a combination of the ICLabel algorithm and manual verification; (8) bad channels were reconstructed via spherical spline interpolation to restore the full 61-channel scalp array; (9) data were re-referenced to the average of the bilateral mastoids (TP9 and TP10); (10) epochs were extracted from −200 to 1000 ms relative to stimulus onset, with baseline correction applied using the −200 to 0 ms pre-stimulus window; and (11) trials with extreme artifacts exceeding ±100 μV were automatically rejected. Following artifact correction and automatic epoch rejection, the 32 retained participants had an average of 170.91 artifact-free trials (SD = 21.94) out of the 192 planned trials, corresponding to a mean retention rate of 89.01% (SD = 11.43%). The mean numbers of retained trials (M ± SD) were 42.06 ± 7.17 for the sweet-romantic condition, 42.72 ± 6.44 for the sweet-friendship condition, 42.88 ± 5.13 for the control-romantic condition, and 43.25 ± 5.25 for the control-friendship condition. Following data cleaning, the MNE package (Gramfort et al., 2013) in Python was used for cross-trial averaging, mean amplitude extraction, and visualization. To minimize the risk of circular analysis, the LPP region of interest (ROI) and time window were defined a priori based on previous literature (Cuthbert et al., 2000; Hajcak et al., 2010; Schupp et al., 2006). Grand-average waveforms collapsed across all experimental conditions were

inspected descriptively after the ROI and time window had been specified and were not used to modify these analysis parameters. LPP was quantified as the mean amplitude across P3, Pz, and P4 from 500–700 ms. Exploratory analyses of the N2 component are reported in the Supplementary Materials and were not part of the primary hypotheses.

Data analysis

Experiment 1 employed a 2 (Taste: Sweet, Control) × 2 (Picture Type: Romantic, Friendship) within-subjects design. Valence and arousal ratings served as the behavioral dependent variables, and mean LPP amplitude served as the electrophysiological dependent variable. Separate repeated-measures ANOVAs were conducted for valence, arousal, and LPP amplitude. All statistical analyses were performed using R software (version 4.6.0). The significance level was set at a two-tailed $p < .05$. For follow-up decomposition of significant interactions, p values within each family of simple-effect comparisons were adjusted using Holm's sequential procedure (reported as p_{Holm} in text) to control the family-wise error rate. To express the Taste × Picture Type interaction as a difference-of-differences, the romantic–friendship LPP difference was calculated separately for the sweet and control conditions, and these within-participant contrasts were then compared. The interaction contrast was defined as (Control Romantic − Control Friendship) − (Sweet Romantic − Sweet Friendship), with Cohen's dz reported as the standardized effect size.

Results

Behavioral data

Manipulation check

A paired-samples t-test on the subjective sweetness ratings of the gustatory materials revealed a significant difference between the two conditions, $t(31) = 39.709$, $p < .001$, Cohen's $dz = 7.020$. Participants perceived the rock sugar in the sweet condition as substantially sweeter ($M = 7.625$, $SE = 0.154$), whereas ratings for the white kidney beans in the control condition were close to the tasteless endpoint of the scale ($M = 0.469$, $SE = 0.100$), showing a difference in perceived sweetness between the two conditions.

Valence

A repeated-measures ANOVA on the valence scores revealed a significant main effect of taste condition, $F(1, 31) = 6.477$, $p = .016$, $\eta_p^2 = .173$, indicating that valence ratings in the sweet condition ($M = 5.728$, $SE = 0.159$) were significantly higher than those in the control condition ($M = 5.536$, $SE = 0.145$); the main effect of picture type was not significant, $F(1, 31) = 0.125$, $p = .726$, $\eta_p^2 = .004$; and the interaction between taste condition and picture type was not significant, $F(1, 31) = 0.043$, $p = .837$, $\eta_p^2 = .001$.

Arousal

A repeated-measures ANOVA on the arousal scores showed a significant main effect of taste condition, $F(1, 31) = 8.387$, $p = .007$, $\eta_p^2 = .213$, demonstrating that arousal ratings in the sweet condition ($M = 5.316$, $SE = 0.169$) were significantly higher than those in the control condition ($M = 5.094$, $SE = 0.148$); the main effect of picture type was not significant, $F(1, 31) = 0.046$, $p = .832$, $\eta_p^2 = .001$; and the interaction between taste condition and picture type was not significant, $F(1, 31) = 2.713$, $p = .110$, $\eta_p^2 = .080$.

Taken together, the behavioral results indicate a general effect of sweet taste on explicit

affective evaluations rather than a picture-type-specific effect. Behavioral results for valence and arousal ratings in the picture evaluation task are summarized in **Table 1.**

Table 1

Repeated-Measures ANOVA Results for Valence and Arousal Ratings in the Picture Evaluation Task (M ± SE)

		Sweet Condition	Control Condition	F_{Taste}	$F_{Picture}$	$F_{Taste\times Picture}$
Valence	total	5.728 ± 0.159	5.536 ± 0.145	6.477*	0.125	0.043
	Opposite-sex romantic pictures	5.715 ± 0.155	5.530 ± 0.145			
	Same-sex friendship pictures	5.741 ± 0.169	5.542 ± 0.152			
Arousal	total	5.316 ± 0.169	5.094 ± 0.148	8.387*	0.046	2.713
	Opposite-sex romantic pictures	5.288 ± 0.169	5.115 ± 0.148			
	Same-sex friendship pictures	5.345 ± 0.172	5.074 ± 0.150			

Note. F_{Taste} represents the main effect of taste condition; $F_{Picture}$ represents the main effect of picture type; $F_{Taste\times Picture}$ represents the interaction effect. * $p < .05$.

ERP data

LPP

A repeated-measures ANOVA on the mean amplitudes of the LPP component indicated that the main effect of taste condition was not significant, $F(1, 31) = 1.007$, $p = .323$, $\eta_p^2 = .031$; the main effect of picture type was significant, $F(1, 31) = 4.181$, $p = .049$, $\eta_p^2 = .119$, demonstrating that the LPP amplitude elicited by opposite-sex romantic pictures ($M = 7.499$ μV, $SE = 0.406$ μV) was larger than that elicited by same-sex friendship pictures ($M = 6.874$

μV, *SE* = 0.368 μV); and the interaction between taste condition and picture type was significant, $F(1, 31) = 5.004$, $p = .033$, $\eta_p^2 = .139$. Further simple-effect analyses yielded the following results: under the control condition, the simple effect of picture type was significant, $F(1, 31) = 9.390$, $p_{Holm} = .009$, $\eta_p^2 = .232$, with opposite-sex romantic pictures ($M = 8.000$ μV, $SE = 0.543$ μV) eliciting a significantly larger LPP amplitude than same-sex friendship pictures ($M = 6.703$ μV, $SE = 0.511$ μV). Under the sweet condition, the simple effect of picture type was not statistically significant, $F(1, 31) = 0.013$, $p_{Holm} = .910$, $\eta_p^2 < .001$. Across different picture types, for opposite-sex romantic pictures, the simple effect of taste condition did not reach statistical significance, $F(1, 31) = 4.151$, $p_{Holm} = .100$, $\eta_p^2 = .118$. For same-sex friendship pictures, the simple effect of taste condition was likewise not significant, $F(1, 31) = 0.754$, $p_{Holm} = .392$, $\eta_p^2 = .024$. To directly quantify the interaction, the romantic–friendship LPP difference was 1.297 μV in the control condition and −0.049 μV in the sweet condition. The resulting difference-of-differences was 1.345 μV ($SE = 0.601$, 95% CI [0.119, 2.572]), $t(31) = 2.237$, $p = .033$, Cohen's $dz = 0.395$.

Thus, the significant Taste × Picture Type interaction reflected a reduction in romantic–friendship LPP differentiation under sweetness, as confirmed by the difference-of-differences analysis. As a robustness check, block order was additionally included as a between-subjects factor. The critical Taste × Picture Type × Order interaction was not significant, $F(1, 30) = 1.264$, $p = .270$, $\eta p^2 = .040$. The Taste × Picture Type interaction remained significant after accounting for Order, $F(1, 30) = 5.046$, $p = .032$, $\eta p^2 = .144$. These results provided no evidence that block order moderated the critical Taste × Picture Type interaction. Full results are provided in the Supplementary Materials. The grand-average LPP waveforms and scalp

topographies are presented in **Fig. 1**. Corresponding LPP statistics are summarized in **Table 2**.

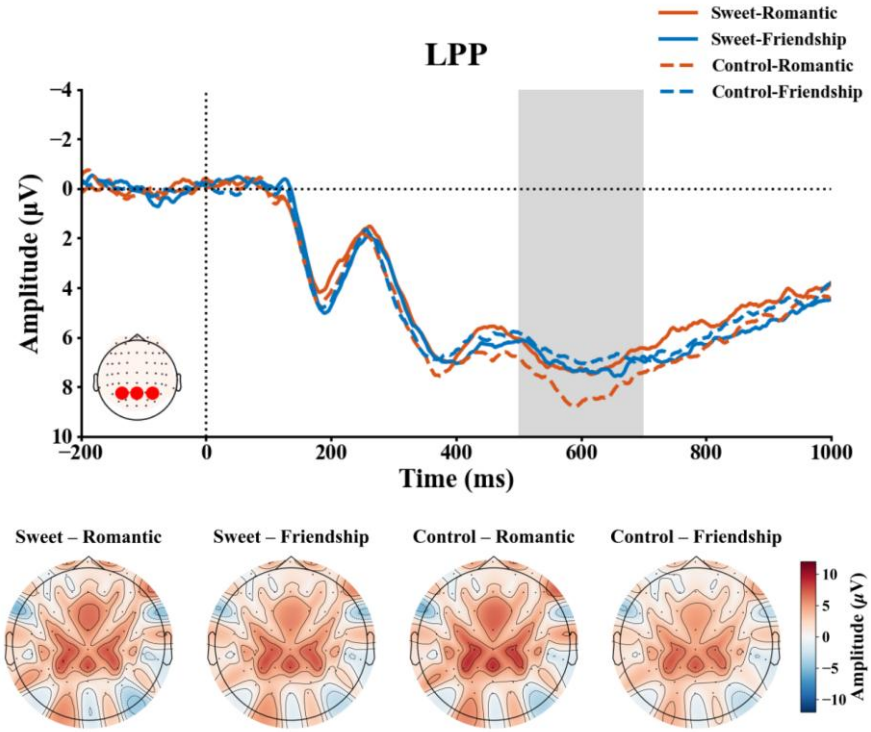


Fig. 1 Grand-average LPP waveforms and scalp topographies in Experiment 1. LPP responses at P3, Pz, and P4, using the 500–700 ms analysis window.

Table 2

Repeated-Measures ANOVA Results for LPP Mean Amplitudes in Experiment 1

Component	Sweet Condition	Control Condition	F_{Taste}	$F_{Picture}$	$F_{Taste \times Picture}$
LPP					
Total	7.021 ± 0.400	7.352 ± 0.385	1.007	4.181*	5.004*
Opposite-sex romantic pictures	6.997 ± 0.606	8.000 ± 0.543			
Same-sex friendship pictures	7.045 ± 0.526	6.703 ± 0.511			

Note. Data are presented as mean ± standard error ($M \pm SE$) in microvolts (μV). * $p < .05$.

In summary, Experiment 1 revealed different patterns at the behavioral and electrophysiological levels: sweet taste generally increased explicit affective ratings, whereas romantic–friendship LPP differentiation evident in the control condition was attenuated under sweetness. However, two questions remained. First, because Experiment 1 required explicit affective evaluation of each picture, it remained unclear whether the observed late-stage modulation would also emerge during passive viewing in the absence of explicit evaluative demands. Second, Experiment 1 did not determine whether the modulation varied with the affective valence of intimate social stimuli. Experiment 2 therefore adopted a passive-viewing paradigm and included positive, negative, and neutral interaction pictures to examine whether a conceptually related LPP pattern would emerge in the absence of explicit evaluation and whether this modulation varied as a function of emotional valence.

Experiment 2

Method

Participants

A total of 62 heterosexual female participants were initially recruited for Experiment 2 (inclusion criteria were identical to those in Experiment 1), with 32 participants in the sweet group and 30 in the control group. During EEG preprocessing, six participants were excluded because of excessive EEG artifacts (four from the sweet group and two from the control group), yielding a final sample of 56 participants, with 28 participants in each group. To evaluate statistical power, an a priori power analysis was conducted using G*Power 3.1.9.7 (Faul et al., 2007). In accordance with our primary hypothesis—specifically testing the between-within

interaction between group and picture type in a 2 (Group: sweet vs. control) × 3 (Picture Type: positive, negative, neutral) mixed design—the test was configured using the "ANOVA: Repeated measures, within–between interaction" module. The parameters were preset to a medium effect size ($f = 0.25$), a significance level of $\alpha = .05$, a statistical power of $1 - \beta = .80$, two groups, and three repeated measurements. Assuming a moderate correlation among repeated measures ($r = .50$) and that the sphericity assumption was met (nonsphericity correction parameter $\epsilon = 1.0$), the required minimum total sample size to detect this interaction effect was calculated to be 28 participants. The final sample therefore exceeded the minimum sample size estimated by the a priori power analysis. The ethical approval and informed consent procedures for this experiment were identical to those in Experiment 1.

Stimulus materials

Gustatory materials

The selection of gustatory materials was identical to that in Experiment 1.

Affect measurement

To assess potential baseline mood differences between groups, participants completed the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) prior to the formal experiment. The PANAS comprises 20 items assessing positive and negative affect, with item scores summed separately to yield Positive Affect (PA) and Negative Affect (NA) scores.

Picture materials

The pictures were collected from publicly accessible online sources and were

subsequently screened and standardized for use as experimental stimuli. In Experiment 2, pictures depicting opposite-sex interactions were subdivided into three categories based on emotional valence: positive pictures (displaying intimate and joyful interactions between partners), negative pictures (displaying conflictual interactions such as arguing and blaming), and neutral pictures (displaying calm, routine interactions); a total of 240 pictures were initially screened. Subsequently, 16 female volunteers who did not participate in the formal experiment were recruited to evaluate the pictures' valence (1 = extremely unpleasant, 9 = extremely pleasant) and arousal (1 = extremely calm, 9 = extremely excited) using a 9-point scale in a pilot assessment. Based on the evaluation results, 40 pictures from each category (120 pictures in total) were ultimately selected as the formal experimental materials. Specifically, the selected positive, negative, and neutral pictures had mean valence ratings targeted at 7 ± 0.5, 3 ± 0.5, and 5 ± 0.5, respectively. Item-based one-way ANOVAs revealed significant effects of picture category on both valence ratings, $F(2, 117) = 1374$, $p < .001$, $\eta p^2 = .959$, and arousal ratings, $F(2, 117) = 28.57$, $p < .001$, $\eta p^2 = .328$, with post hoc pairwise comparisons (Holm-corrected) indicating no significant difference in arousal between positive and negative pictures ($p_{Holm} = .176$), whereas both elicited significantly higher arousal than neutral pictures ($ps_{Holm} < .001$). All selected pictures were in color, and their physical properties, including size, resolution, luminance, and saturation, were standardized prior to the formal experiment.

Procedure

The laboratory environment and EEG preparation procedures were identical to those in Experiment 1. Experiment 2 primarily consisted of a gustatory manipulation and a passive

picture-viewing task, with the specific procedure as follows: first, experimental instructions were presented to the participants. After ensuring that participants fully understood the experimental task, the experimenter randomly assigned them to either the sweet group or the control group, providing them with rock sugar or white kidney beans, respectively, as the gustatory material. Next, participants were required to taste the assigned material and rate its perceived sweetness using a 10-point scale (0 = tasteless, 9 = extremely sweet). Upon completion of the subjective ratings, participants entered the formal passive picture viewing task. Throughout the entire formal experiment (i.e., during EEG recording), participants were required to continuously maintain a piece of rock sugar or a white kidney bean in their mouths. This task comprised a total of 120 trials (40 positive, 40 negative, and 40 neutral pictures), with all pictures presented in a completely random sequence. The detailed procedure for a single trial was as follows: a black fixation cross first appeared in the center of the screen for 500 ms, followed by the presentation of the experimental picture for 1500 ms. During picture presentation, participants were instructed to view each picture attentively without making any overt response. Each picture was followed by a 1000-ms blank inter-trial interval before the next trial began automatically.

EEG recording and preprocessing

EEG recording and preprocessing procedures were identical to those in Experiment 1. Following artifact rejection, participants retained an average of 98.79 artifact-free trials (*SD* = 22.47) out of the 120 planned trials, corresponding to a mean retention rate of 82.32% (*SD* = 18.72%). The sweet group retained an average of 101.96 trials (*SD* = 17.24), corresponding to

a retention rate of 84.97% (*SD* = 14.37%), whereas the control group retained an average of 95.61 trials (*SD* = 26.64), corresponding to a retention rate of 79.67% (*SD* = 22.20%). Consistent with Experiment 1, the same a priori-defined parietal ROI (P3, Pz, P4) and 500–700 ms time window were used to quantify the LPP in Experiment 2. Grand-average waveforms collapsed across all Experiment 2 conditions were inspected only descriptively.

Data analysis

Experiment 2 employed a 2 (Taste Group: Sweet, Control) × 3 (Picture Type: Positive, Negative, Neutral) mixed design, with Taste Group as the between-subjects factor and Picture Type as the within-subjects factor. The dependent variable was the mean amplitude of the late positive potential (LPP) elicited during passive viewing of the different picture types. A mixed-design analysis of variance (ANOVA) was conducted to examine the main effects of taste group and picture type and their interaction. The sphericity assumption for the within-subject factor was assessed using Mauchly's test, and Greenhouse–Geisser corrections were applied when this assumption was violated. Within each family of post hoc pairwise comparisons and simple-effect tests, p values were adjusted using Holm's sequential procedure to control the family-wise error rate. To directly characterize a significant Group × Picture Type interaction, two follow-up interaction contrasts compared the within-participant positive–neutral and positive–negative LPP differences between the sweet and control groups, with the contrast direction defined as control minus sweet. These two interaction contrasts were treated as one comparison family and were likewise adjusted using the Holm procedure. Cohen's d was used to quantify the standardized between-group difference in the corresponding within-participant contrasts. The significance level for all statistical tests was set at two-tailed $p < .05$. All statistical analyses

were performed in R (version 4.6.0).

Results

Subjective ratings and manipulation check

Independent-samples t-tests on baseline mood measurements revealed no significant differences between the sweet and control groups (both *ps* > .30; positive affect: $t(54) = -1.043$, $p = .302$, Cohen's $d = -0.279$; negative affect: $t(54) = -0.857$, $p = .395$, Cohen's $d = -0.229$), indicating that no statistically detectable baseline differences were observed between the groups. In addition, an independent-samples t-test on the subjective ratings of the gustatory materials revealed a significant between-group difference in perceived sweetness, $t(54) = 37.684$, $p < .001$, Cohen's $d = 10.072$. Participants in the sweet condition rated rock sugar as substantially sweeter ($M = 7.679$, $SE = 0.155$), whereas those in the control condition rated white kidney beans close to the tasteless endpoint of the scale ($M = 0.357$, $SE = 0.117$), confirming a clear difference in perceived sweetness between the two conditions. The results are summarized in **Table 3**.

Table 3

Independent-Samples t-Test Results for Baseline Mood and Subjective Sweetness Ratings in Experiment 2 (M ± SE)

Measure	Sweet Group ($n = 28$)	Control Group ($n = 28$)	t
PA	24.821 ± 1.121	26.464 ± 1.106	−1.043
NA	16.036 ± 1.100	17.357 ± 1.079	−0.857
Sweetness rating	7.679 ± 0.155	0.357 ± 0.117	37.684***

*Note. PA = Positive Affect; NA = Negative Affect. *** $p < .001$.*

ERP data

LPP

A mixed-design analysis of variance (ANOVA) was conducted to examine the mean amplitude of the LPP component. Mauchly's test of sphericity indicated that the assumption of sphericity was met ($W = 0.945$, $p = .226$). The ANOVA revealed no significant main effect of group, $F(1, 54) = 0.246$, $p = .622$, $\eta_p^2 = .005$. The main effect of picture type also did not reach statistical significance, $F(2, 108) = 2.937$, $p = .057$, $\eta_p^2 = .052$. Importantly, the interaction between group and picture type was significant, $F(2, 108) = 3.461$, $p = .035$, $\eta_p^2 = .060$, indicating that LPP differentiation across picture categories varied as a function of taste group. Further simple-effect analyses showed a significant effect of picture type in the control group, $F(2, 54) = 4.567$, $p_{Holm} = .029$, $\eta_p^2 = .145$. Holm-corrected pairwise comparisons further showed that positive pictures ($M = 7.906$ μV, $SE = 0.802$ μV) elicited a significantly larger LPP amplitude than neutral pictures ($M = 6.384$ μV, $SE = 0.704$ μV; mean difference = 1.522 μV, $t(27) = 3.064$, $p_{Holm} = .015$, Cohen's $d_z = 0.579$), whereas the difference between positive and negative pictures did not reach significance ($M = 6.869$ μV, $SE = 0.866$ μV; $t(27) = 2.016$, $p_{Holm} = .108$, Cohen's $d_z = 0.381$), nor did the difference between negative and neutral pictures ($t(27) = 0.911$, $p_{Holm} = .370$, Cohen's $d_z = 0.172$). In contrast, the simple effect of picture type was not significant in the sweet group, $F(2, 54) = 1.500$, $p_{Holm} = .232$, $\eta_p^2 = .053$, with no statistically significant differences among positive ($M = 6.374$ μV, SE = 0.750 μV), negative ($M = 7.020$ μV, SE = 0.668 μV), and neutral pictures ($M = 6.290$ μV, SE = 0.727 μV; all $ps_{Holm} \geq .360$). Thus, no pairwise category differences reached statistical significance within the sweet group. Simple-effect analyses of group within each picture category revealed no significant group

differences for positive pictures, $F(1, 54) = 1.946$, $p_{Holm} = .507$, $\eta_p^2 = .035$, negative pictures, $F(1, 54) = 0.019$, $p_{Holm} > .99$, $\eta_p^2 < .001$, or neutral pictures, $F(1, 54) = 0.009$, $p_{Holm} > .99$, $\eta_p^2 < .001$. The grand-average ERP waveforms and scalp topographies of the LPP component are presented in **Fig. 2**.

To directly characterize the significant interaction, two follow-up interaction contrasts compared the magnitude of the positive–neutral and positive–negative LPP differences between groups (control minus sweet). Positive–neutral differentiation was significantly larger in the control group (M = 1.521 μV, SD = 2.628) than in the sweet group (M = 0.085 μV, SD = 1.899), yielding a difference-of-differences estimate of 1.437 μV (SE = 0.613, 95% CI [0.208, 2.665]), t(54) = 2.345, unadjusted p = .023, Holm-adjusted p = .045, Cohen's d = 0.627. Positive–negative differentiation was also significantly larger in the control group (M = 1.037 μV, SD = 2.722) than in the sweet group (M = −0.646 μV, SD = 2.912), yielding a difference-of-differences estimate of 1.683 μV (SE = 0.753, 95% CI [0.173, 3.194]), t(54) = 2.235, unadjusted p = .030, Holm-adjusted p = .045, Cohen's d = 0.597.

Taken together, the two follow-up interaction contrasts revealed significant between-group differences in both positive–neutral and positive–negative LPP differentiation after Holm correction, with larger differentiation in the control group than in the sweet group. These results further demonstrate that sweetness reduced the relative LPP advantage of positive social stimuli compared with neutral and negative stimuli. Corresponding statistical results for LPP mean amplitudes are summarized in **Table 4**.

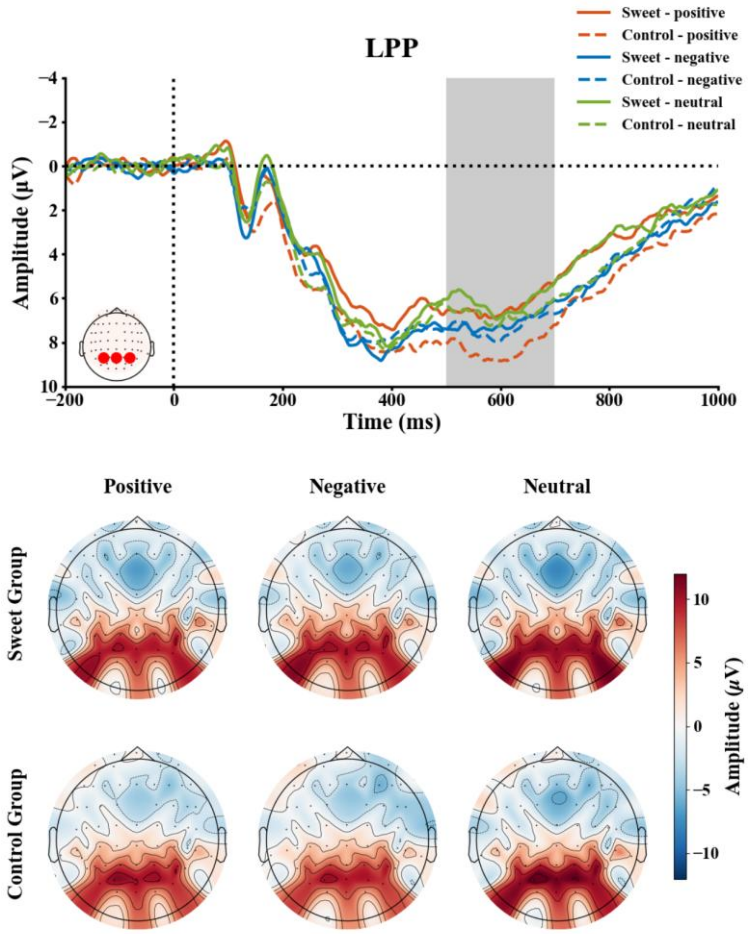


Fig. 2 Grand-average LPP waveforms and scalp topographies in Experiment 2. LPP responses at P3, Pz, and P4, using the 500–700 ms analysis window.

Table 4

Mixed-Design ANOVA Results for LPP Mean Amplitudes in Experiment 2

Component	Sweet Group (n = 28)	Control Group (n = 28)	F_{Group}	$F_{Picture}$	$F_{Group \times Picture}$
LPP					
Total	6.561 ± 0.664	7.052 ± 0.736	0.246	2.937	3.461*
Positive	6.374 ± 0.750	7.906 ± 0.802			
Negative	7.020 ± 0.668	6.869 ± 0.866			
Neutral	6.290 ± 0.727	6.384 ± 0.704			

Note. Data are presented as mean ± standard error *(M ± SE)* in microvolts (μV). Mix

ed-design ANOVA was conducted with Group (Sweet vs. Control) as the between-subjects factor and Picture Type (Positive, Negative, Neutral) as the within-subjects factor. * $p < .05$.

Discussion

Across two ERP experiments, the present study examined how sweet taste modulates explicit affective evaluation and late-stage electrophysiological processing of intimacy-related social information. The findings revealed distinct behavioral and electrophysiological patterns. In Experiment 1, sweet taste increased overall valence and arousal ratings, whereas both experiments showed attenuated category-related LPP differentiation under sweetness. Together, these findings suggest that sweet taste may differentially influence explicit affective evaluation and the late-stage neural processing of social information.

Late-stage electrophysiological modulation by sweet taste

The late positive potential (LPP) is commonly associated with sustained attention and elaborative processing of emotionally or motivationally salient information (Cuthbert et al., 2000; Hajcak et al., 2010). Previous research has shown that affective contexts can modulate subsequent LPP responses. Czerwon et al. (2013) found that auditory primes containing syntactic parallelisms reduced LPP amplitudes elicited by subsequently presented positive faces. Similarly, Flaisch et al. (2008) demonstrated that preceding emotional pictures reduced LPP amplitudes to subsequent pictures, interpreting this effect in terms of competition for processing resources. These findings suggest that previously established affective contexts can influence the sustained processing of subsequent emotional information. In the present study,

sweet taste provided an ongoing rewarding sensory context during social information processing. The reduced LPP advantage of romantic or positive social stimuli is consistent with a reward-competition-based interpretation, in which the presence of a rewarding sensory context may alter the relative motivational priority of subsequently presented social information. These findings extend previous evidence on affective-context modulation of the LPP to the interaction between gustatory experience and social-affective processing.

Different behavioral and electrophysiological patterns

Explicit affective evaluations and LPP differentiation reflect different aspects of social-affective processing. Previous research has linked sweetness to more favorable evaluations of potential romantic relationships (Ren et al., 2015) and positive emotional concepts (Zhou & Tse, 2020). Consistent with the affect-as-information perspective and the Affect Infusion Model, the positive affective associations of sweetness may contribute to more favorable subjective evaluations of social information (Clore & Huntsinger, 2007; Forgas, 1995). By contrast, the LPP is associated with the motivational significance and sustained processing of stimuli rather than serving as a direct measure of subjective pleasantness (Hajcak & Foti, 2020). Previous research has also demonstrated that subjective affective ratings and LPP responses do not necessarily vary in parallel (Sambuco et al., 2025). In the present study, sweet taste increased overall valence and arousal ratings in Experiment 1, whereas both experiments revealed reduced LPP differentiation favoring romantic or positive social stimuli. These findings suggest that more positive explicit evaluations do not necessarily correspond to stronger late-stage neural differentiation between social stimulus categories. One possible

explanation is that ongoing sweet-taste stimulation alters the relative motivational priority of subsequently presented social information, thereby influencing its sustained neural processing.

Limitations and Future Directions

Several limitations should be acknowledged. First, the sample was restricted to heterosexual women, limiting the generalizability of the findings. Second, the pleasantness of the gustatory materials was not independently assessed, leaving the sensory and hedonic properties of sweetness undifferentiated. Third, relationship category and dyad sex composition were confounded in Experiment 1, while emotional valence and arousal were not fully dissociated across picture categories in Experiment 2. Finally, the use of static social images limits ecological validity. Future research could employ more diverse samples, better-controlled stimuli, and dynamic social interaction paradigms to further examine the effects of sweetness on social-affective processing and the underlying reward-related mechanisms.

Conclusion

The present study demonstrated that sweet taste increased overall explicit valence and arousal ratings in Experiment 1 and modulated category-related LPP differentiation across two ERP experiments. Specifically, sweetness attenuated the relative late-stage processing advantage of romantic or positive social information. These findings extend previous research on sweetness and social cognition by providing electrophysiological evidence of gustatory modulation of social-affective processing.

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Supplementary Materials

S1. Exploratory N2 analysis in Experiment 1

Method

Experiment 1 used the EEG acquisition and preprocessing pipeline reported in the main manuscript. N2 was quantified as mean amplitude across F3, Fz, and F4 from 230–300 ms. A 2 (Taste: Sweet, Control) × 2 (Picture Type: Romantic, Friendship) repeated-measures ANOVA was conducted, followed by Holm-corrected simple-effect analyses where appropriate.

Results

A repeated-measures ANOVA on the mean amplitudes of the N2 component revealed that the main effect of taste condition was not significant, $F(1, 31) = 0.200$, $p = .658$, $\eta_p^2 = .006$; the main effect of picture type was not significant, $F(1, 31) = 2.007$, $p = .167$, $\eta_p^2 = .061$; however, the interaction between taste condition and picture type was significant, $F(1, 31) = 4.488$, $p = .042$, $\eta_p^2 = .126$. Regarding the effect of picture type across taste conditions, under the sweet condition, opposite-sex romantic pictures ($M = -5.895$ μV, $SE = 0.895$ μV) elicited a numerically more negative N2 amplitude than same-sex friendship pictures ($M = -4.784$ μV, $SE = 0.832$ μV), $F(1, 31) = 5.098$, $p_{Holm} = .062$, $\eta_p^2 = .141$, but this Holm-corrected simple effect did not reach statistical significance. Under the control condition, the simple effect of picture type was not significant, $F(1, 31) = 0.144$, $p_{Holm} = .707$, $\eta_p^2 = .005$. Regarding the effect of taste condition across picture types, the simple effect of taste condition was not significant for either opposite-sex romantic pictures, $F(1, 31) = 0.541$, $p_{Holm} = .468$, $\eta_p^2 = .017$, or same-sex friendship pictures, $F(1, 31) = 2.689$, $p_{Holm} = .222$, $\eta_p^2 = .080$.

The corresponding waveform and scalp topography are shown in Supplementary

Figure S1(a).

Supplementary Table S1

Exploratory N2 Results in Experiment 1

Component	Sweet Condition	Control Condition	F_{Taste}	$F_{Picture}$	$F_{Taste \times Picture}$
N2					
Total	−5.340 ± 0.618	−5.545 ± 0.653	0.200	2.007	4.488*
Opposite-sex romantic pictures	−5.895 ± 0.895	−5.468 ± 0.927			
Same-sex friendship pictures	−4.784 ± 0.832	−5.622 ± 0.915			

Note. Data are presented as mean ± standard error ($M \pm SE$) in microvolts (μV). * $p < .05$.

S2. Exploratory N2 analysis in Experiment 2

Method

Experiment 2 used the same N2 definition as Experiment 1: mean amplitude across F3, Fz, and F4 from 230–300 ms. A 2 (Group: Sweet, Control) × 3 (Picture Type: Positive, Negative, Neutral) mixed-design ANOVA was conducted, followed by Holm-corrected comparisons where appropriate.

Results

A mixed-design analysis of variance (ANOVA) was conducted to examine the mean amplitudes of the N2 component. Mauchly's test of sphericity indicated that the assumption of sphericity was met ($W = 0.974$, $p = .495$). The ANOVA results revealed that the main effect of group was not significant, $F(1, 54) = 0.555$, $p = .459$, $\eta_p^2 = .010$; however, the main effect of

picture type was significant, $F(2, 108) = 4.356$, $p = .015$, $\eta_p^2 = .075$. Specifically, Holm-corrected pairwise comparisons showed that neutral pictures ($M = -5.549$ μV, $SE = 0.554$ μV) elicited a significantly more negative N2 amplitude than positive pictures ($M = -4.450$ μV, $SE = 0.614$ μV; mean difference = −1.100 μV, $t(55) = -2.933$, $p_{Holm} = .015$, Cohen's $d_z = -0.392$), whereas their difference from negative pictures did not reach significance ($M = -4.901$ μV, $SE = 0.598$ μV; mean difference = −0.649 μV, $t(55) = -1.887$, $p_{Holm} = .129$, Cohen's $d_z = -0.252$); the difference between positive and negative pictures was likewise not significant (mean difference = 0.451 μV, $t(55) = 1.140$, $p_{Holm} = .259$, Cohen's $d_z = 0.152$); the interaction between group and picture type was not significant, $F(2, 108) = 0.257$, $p = .774$, $\eta_p^2 = .005$.

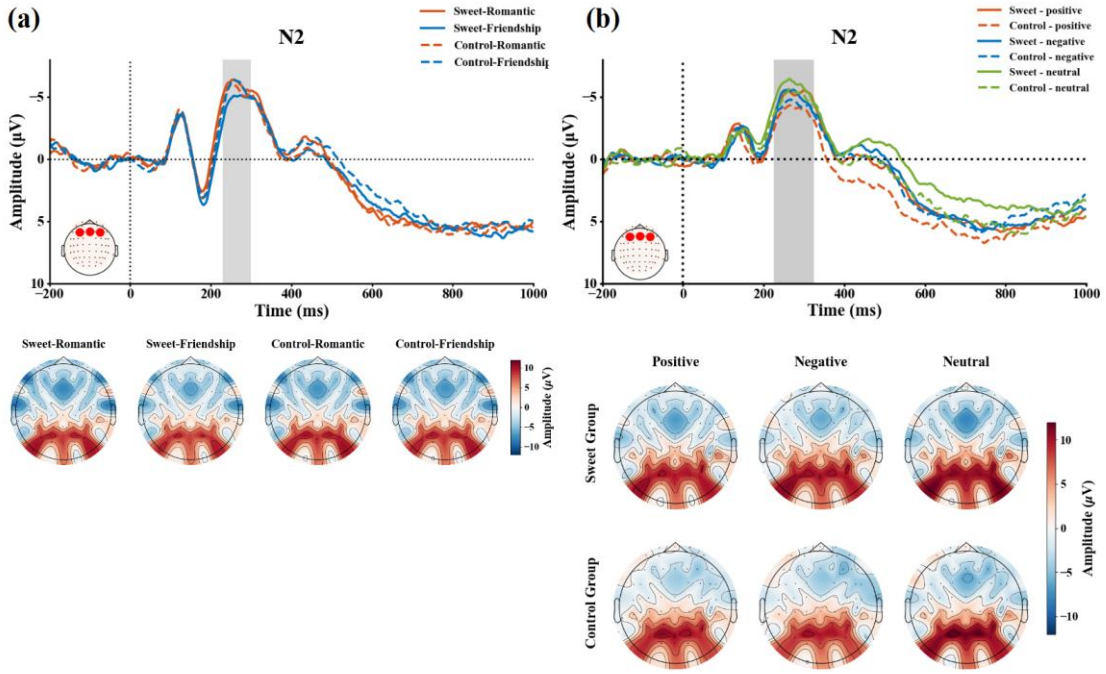
The corresponding waveform and scalp topography are shown in Supplementary **Figure S1(b)**.

Supplementary Table S2

Exploratory N2 Results in Experiment 2

Component	Sweet Group ($n = 28$)	Control Group ($n = 28$)	F_{Group}	$F_{Picture}$	$F_{Group \times Picture}$
N2					
Total	−5.377 ± 0.727	−4.556 ± 0.828	0.555	4.356*	0.257
Positive	−5.014 ± 0.814	−3.885 ± 0.923			
Negative	−5.249 ± 0.801	−4.552 ± 0.897			
Neutral	−5.868 ± 0.731	−5.230 ± 0.841			

Note. Data are presented as mean ± standard error (M ± SE) in microvolts (μV). * $p < .05$.



Supplementary Figure S1. Exploratory N2 waveforms and scalp topographies in Experiments 1 and 2. (a) Experiment 1: N2 responses at F3, Fz, and F4, using the 230–300 ms analysis window. (b) Experiment 2: N2 responses at F3, Fz, and F4, using the 230–300 ms analysis window.