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"How Liquid Foundations Modulate the Facial Aesthetic Perception: Unveiling the Implicit Skin Tone Preferences of Chinese Women through Electrophysiological Indices"

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1. Introduction

Facial attractiveness refers to the aesthetic appeal of individuals' facial features. When an individual interacts with others, facial appearance provides the most important non-verbal information in humans conveys. Compared to less attractive appearance, those with higher attractiveness often imply better social benefits(Van Leeuwen & Neil Macrae, 2004), including being evaluated more positively(Little et al., 2011), perceived as healthier(Jones et al., 2001), seen as possessing more socially desirable qualities(Dion et al., 1972), and had more advantages in mate choice (Rhodes, 2006). From the evolutionary perspective, high facial attractiveness is considered a health markers associated with good genes (Little et al., 2011; Mitchem et al., 2014).

Although facial attractiveness has been shown to be stable (Rhodes et al., 2001), the use of cosmetics can alter the perception of facial features in a manner similar to geometric illusions(McKone & Robbins, 2011). The human visual system perceives and recognizes faces through holistic processing(McKone & Robbins, 2011), where facial features are interdependent. The use of cosmetics can not only alter skin tone but also enhance skin evenness(Batres et al., 2019), accentuate facial features(Jones et al., 2015; Russell, 2009) and modify the single facial feature (such as the eyes, nose, or mouth). This can have a significant impact on the perception of the entire face, thereby influencing the perception of facial attractiveness. Given its widespread practice, the effects of cosmetics are both profound and far-reaching. To assess the impact of cosmetics on facial perception, Morikawa et al. (2015) used a psychophysical method to measure the perceived enlargement in depth and size of the eyes in photographs of female models wearing eye makeup. The results showed that, although the actual eye size was identical, the eyes were perceived as larger compared to photographs of models without any eye makeup and larger eyes are often considered a more attractive facial feature(Baudouin & Tiberghien, 2004). This explains why makeup can significantly enhance facial attractiveness: by carefully adjusting certain features, makeup can optimize the overall harmony and aesthetic appeal of the face, thereby increasing its attractiveness.

In daily life, the use of cosmetics has become a way for many women to enhance their confidence and appearance. It can even out skin tone, cover facial blemishes, redness, and other pigmentation, making the skin look more uniform and smooth. The perception of skin tone plays a crucial role in human health judgments and has attracted considerable interest(Little et al., 2011).Many studies has suggested that facial skin tone has great influence on attractiveness (Fink et al., 2001; Frisby, 2006). A series of empirical studies have proven that skin tone has a significant effect on the perception of attractiveness and youthfulness in women(Fink et al., 2001, 2006; Vera Cruz, 2018).

The purpose of this study is to utilize event-related potentials (ERPs) technology to explore the specific impact of different foundation shades on facial attractiveness, with a particular focus on the preferences of Chinese consumers. Although existing neural research has revealed the effects of cosmetics on facial attractiveness and neural responses, these studies are often generalized and lack detailed analysis of specific cosmetic categories, especially in terms of foundation shade selection. Consumers frequently experience confusion when choosing foundation shades. Therefore, this study aims to identify the preferred foundation color range for Chinese consumers through neuroscientific methods, providing scientific evidence to help them make more informed choices and offering guidance for product development in the cosmetics industry.

2. Materials and Methods

2.1. Participants

A total of 32 healthy female participants were recruited to take part in this study. All participants were aged between 18 and 40 years (32.68 ± 5.87 years) and reported regular use of cosmetic products. All participants were categorized as right-handed according to the Edinburgh handedness inventory(Oldfield, 1971), and all had normal or corrected vision. None of the participants had any history of neurological, psychiatric, and/or cardiovascular disease, and had enough cognition to follow simple instructions and understand the objectives of the study. Moreover, experimental process and possible risks were explained to each participant prior to data collection. Written informed consent form was obtained from each person for taking part in the study prior to their involvement.

2.2. Stimuli

Eight female models underwent standardized facial imaging using the VISIA 7 system under controlled lighting. Each applied three commercial foundations (Z15 / N25 / N30) in randomized order using Latin square design, with 15-minute intervals under controlled environment (21℃±1℃, 50%±10% humidity) between applications. Post-application imaging replicated baseline capture parameters. The VISIA system automated facial alignment through contour recognition, generating 32 validated image sets (8 models×4 conditions: bare skin + 3 foundations). All images maintained original black backdrop (RGB 3,3,3) and lighting without post-processing.

2.3. Procedures

The formal experiment were conducted in a dedicated soundproof room. Participants were positioned 60 cm from the display monitor, with visual stimuli centrally presented on a uniform gray background (Figure 1). Facial stimuli (8 models × 4 conditions [bare skin and 3 makeup conditions]) were displayed on a 32-inch LED-backlit LCD monitor (1920×1080 resolution) using E-Prime 3.0 software (Psychology Software Tools). Each trial began with a central white fixation cross displayed on a uniform gray background (RGB 128, 128, 128) for 500 ms. Subsequently, a facial image (514 × 771 pixels, subtending 8.2° × 12.3° of visual angle) was presented at screen center for 1,000 ms, framed by a black border to minimize edge-related visual artifacts. Following stimulus offset, a blank gray screen (identical RGB parameters) appeared for 500 ms, after which a numerical rating prompt was displayed centrally, instructing participants to press numeric keys 1–5 (1 = "very unattractive", 5 = "very attractive") to evaluate the model's aesthetic appeal within an unlimited response window.

A total of 160 trials (8 unique facial images ×4 conditions × 5 repetitions) were presented in semi-randomized order, with constraints preventing immediate repetition of the same model or makeup condition. Stimuli were organized into 4 blocks of 40 trials each, interspersed with mandatory 60-second rest periods to minimize fatigue. Prior to the formal experiment, participants completed 10 practice trials using non-experimental facial images to familiarize themselves with the rating system.

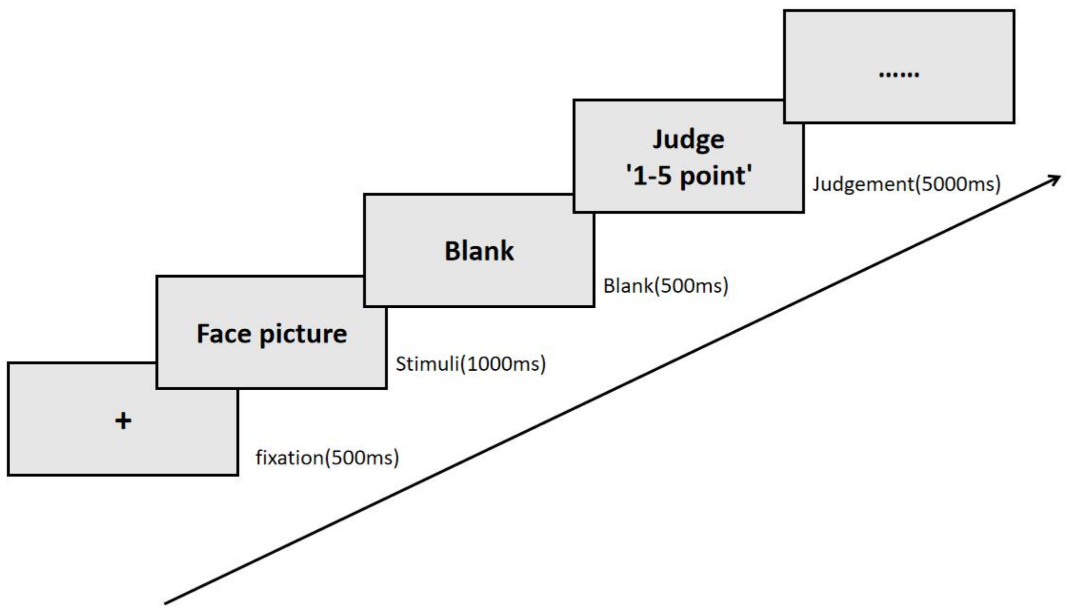

Figure 1. In the aesthetic evaluation task, participants were instructed to attend to the image during the stimulus stage, followed by rating its aesthetic appeal in the judgment stage.

2.4. Statistical analysis of Skin Parameters

Quantitative skin parameters, including Commission Internationale de l'Éclairage (CIE)

L*a*b* color space values (lightness [ΔL*], redness-greenness [Δa*], yellowness-blueness [Δb*]) and Individual Typology Angle (ITA°), were extracted from standardized VISIA-CR facial images of bilateral cheek regions under four experimental conditions (bare skin, Natural [N30], Medium [N25], Fair [Z15]). Baseline-normalized differences (Δ) for each parameter were calculated by subtracting bare skin measurements from post-foundation measurements. Paired-samples t-tests were conducted to evaluate the effects of each foundation shade (Natural, Medium, Fair) against the bare skin baseline for ΔL*, Δa*, Δb*, and ΔITA°. All statistical analyses were performed in MATLAB R2021b (MathWorks, Natick, MA, USA).

2.5. Statistical analysis of Subjective Ratings

Subjective attractiveness ratings, collected on a 5-point Likert scale (1 = "very unattractive" to 5 = "very attractive"), were analyzed to evaluate perceptual differences across the three foundation conditions (Natural [N30], Medium [N25], Fair [Z15]). A one-way repeated-measures ANOVA was conducted with foundation shade as the within-subjects factor (four levels:bare skin, Natural, Medium, Fair), using Greenhouse-Geisser correction for non-sphericity. Post-hoc pairwise comparisons with Bonferroni adjustment were applied to decompose significant main effects. All analyses were performed in MATLAB R2021b (MathWorks, Natick, MA, USA).

2.5. EEG recordings and preprocessing

EEG signals were recorded using a 32-channel BrainProducts ActiCAP system, with electrodes placed according to the international 10–20 system. Fpz was used as the online reference electrode. The EEG system sampled data at 500 Hz, and all electrode impedances were maintained below 5 kΩ to ensure high-quality signal acquisition. A notch filter with 50Hz was adopted to remove power frequency interference during data acquisition. Data were analyzed with EEGLAB (v14_1_2b Toolbox, MATLAB, Swartz Center for Computational Neuroscience, San Diego, CA, USA) . In the pre-processing stage, the offline raw data was amplified with a 0.1–30Hz band-pass filter, and then re-referenced by the common average reference. Independent component analysis (ICA) algorithm was then used to remove the artifacts. Trials with peak-to-peak deflections exceeding ±100μV were also excluded from data analysis.

2.6. Event-related potential analysis of EEG data

EEG data were analyzed using differential waveforms derived by subtracting neural responses to bare skin stimuli from those elicited by the three foundation conditions (Natural [N30], Medium [N25], Fair [Z15]) to isolate makeup-specific neural modulation. For each trial, epochs spanning −200 to 800 ms relative to stimulus onset were extracted, with baseline correction applied to the −200–0 ms pre-stimulus interval. Component-specific electrode clusters were defined according to their established spatiotemporal roles in visual processing: the P1 component (100–140 ms), reflecting early sensory encoding, was analyzed at occipital electrodes (O1, Oz, O2); the N170 component (140–190 ms), associated with structural face processing, was examined at occipito-temporal sites (P7, P8, O1, O2); and the Early Posterior Negativity (EPN; 200–240 ms), linked to intermediate visual analysis, was assessed using the same occipito-temporal cluster (P7, P8, O1, O2) following the previous studies (see in Revers et al., 2023). Differential ERP waveforms were generated by averaging trials within each foundation condition and subtracting the corresponding bare skin baseline. Amplitude measurements from these baseline-corrected differential waves were extracted within component-specific time windows and electrode clusters for subsequent statistical analysis of foundation-induced neural effects.

3. Results

3.1. Subjective Ratings results

All foundation shades significantly enhanced attractiveness ratings versus bare skin ($p<0.001$*), with no inter-shade differences (Table 1.).

Table 1. Mean attractiveness ratings and p value between foundation shades and bare skin

Condition	Rating	vs. Bare Skin (p)
Bare skin	2.64±1.01	-
Z15 (Fair)	3.31±1.38	<0.001
N25 (Medium)	3.32±1.36	<0.001
N30 (Natural)	3.36±1.33	<0.001

3.2. Skin Parameters results

For L* (lightness), pairwise comparisons indicated no significant difference between Natural (N30) and Medium (N25) ($p = 0.217$), while Fair (Z15) demonstrated significantly lower lightness compared to both Natural ($p = 0.001$) and Medium ($p = 0.015$), suggesting that Z15 achieved the most pronounced skin-brightening effect.

In contrast, a* (red-green axis) showed no significant differences among any shade pairs (Natural vs. Medium: $p = 0.908$; Natural vs. Fair: $p = 0.119$; Medium vs. Fair: $p = 0.111$), indicating equivalent efficacy in modulating skin redness across all three foundations.

For b* (yellow-blue axis), all pairwise comparisons reached statistical significance: Natural induced higher yellowness than Medium ($p = 0.017$), while Fair exhibited progressively reduced yellowness compared to both Natural ($p < 0.001$) and Medium ($p < 0.001$), with a clear efficacy gradient (Z15 > N25 > N30).

Similarly, ITA° (skin brightness) differed significantly across all foundation pairs (Natural vs. Medium: $p = 0.024$; Natural vs. Fair: $p < 0.001$; Medium vs. Fair: $p < 0.001$), confirming a whitening effect hierarchy (Z15 > N25 > N30). Normality assumptions were validated for all conditions ($p > 0.05$).

3.3. ERP results

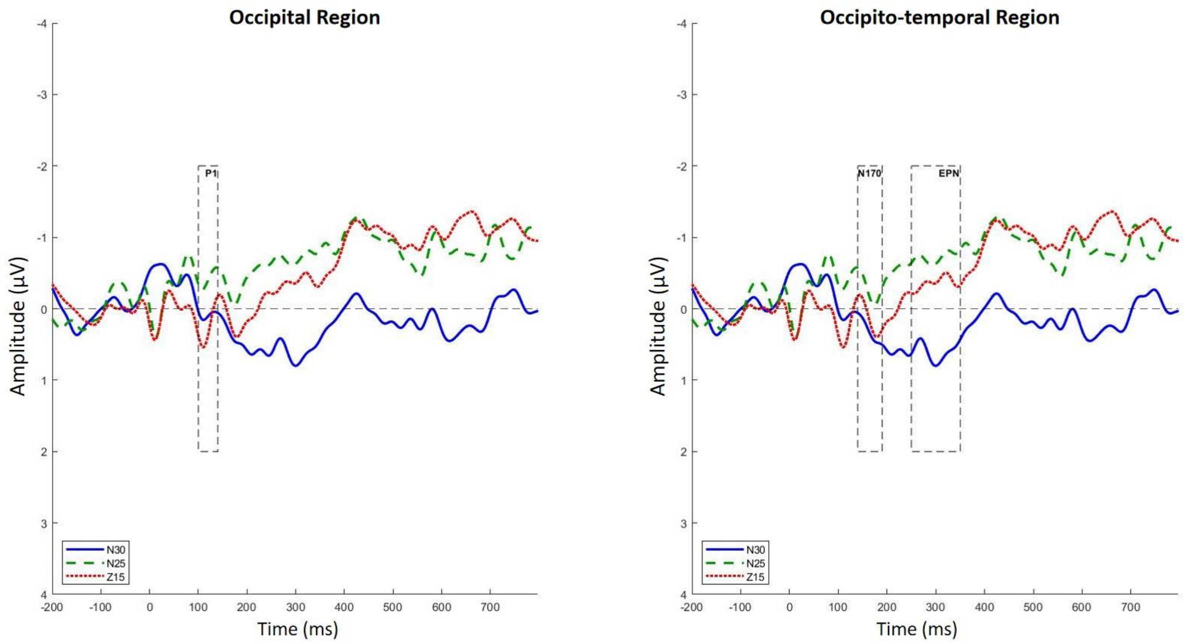

Figure 2. Averaged ERPs from occipital and occipito-temporal regions as a function of foundation condition. Significant group × valence interactions were found for P1 (100–140 ms), N170 (140–190 ms), and EPN (250–350 ms), as marked by dotted rectangles.

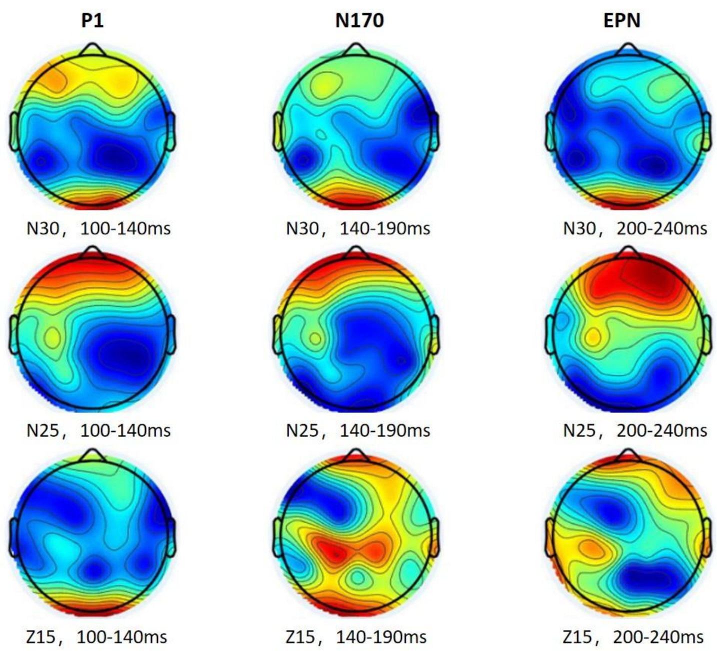

Figure 3. Scalp topographies of ERP amplitudes at three time windows corresponding to P1 (100–140 ms), N170 (140–190 ms), and EPN (200–240 ms), shown separately for each foundation condition. Columns represent conditions (left to right: N30, N25, and Z15), and row represent the respective ERP components. The maps illustrate the spatial distribution of voltage over the scalp, highlighting condition-related modulations of occipital and occipito-temporal activity.

For P1, a significant main effect of foundation conditions was observed ($F(2, 233) = 9.166$, $p < 0.001$, $\eta^2 = 0.068$). Post-hoc comparisons demonstrated that the Medium (N25) foundation elicited markedly reduced P1 amplitudes ($M = -0.3194$ μV) compared to both Natural (N30; $\Delta M = 0.2250$ μV, $p < 0.001$) and Fair (Z15; $\Delta M = 0.1442$ μV, $p < 0.001$).

For the N170 component, associated with structural face processing, a robust main effect of foundation conditions emerged ($F(2, 311) = 10.652$, $p < 0.001$, $\eta^2 = 0.061$), while neither brain region ($F(1, 311) = 0.171$, $p = 0.679$) nor interaction effects ($F(2, 311) = 0.021$, $p = 0.979$) reached significance. The Medium (N25) foundation again exhibited the most attenuated responses ($M = -0.1194$ μV), differing significantly from Natural (N30; $\Delta M = 0.4496$ μV, $p < 0.001$) and Fair (Z15; $\Delta M = 0.4683$ μV, $p < 0.001$).

A parallel pattern was observed for the Early Posterior Negativity (EPN; 200–300 ms), with significant condition modulation ($F(2, 311) = 9.742$, $p < 0.001$, $\eta^2 = 0.056$) and no regional or interactive effects ($p > 0.9$). Here, Medium (N25; $M = -0.1402$ μV) showed suppressed amplitudes relative to both Natural (N30; $\Delta M = 0.4909$ μV, $p < 0.001$) and Fair (Z15; $\Delta M = 0.4817$ μV, $p = 0.019$).

4. Discussion

The present study revealed differential modulation effects of foundation shades on aesthetic cognitive processing through neurophysiological indicators. Although subjective evaluations failed to effectively distinguish aesthetic perception differences across foundation shades, the temporal dynamics of ERP components objectively captured the underlying neural mechanism divergences. ERP results demonstrated that both the Natural (N30) and Fair (Z15) foundations elicited significantly enhanced neural responses during early visual processing stages (50–300 ms post-stimulus), as evidenced by increased amplitudes in the P1, N170, and EPN, compared to the Medium shade (N25). In contrast, the Medium foundation (N25) exhibited systematic suppression of neural activity across all early components, suggesting that its formulation may reduce the visual salience of facial structural information, thereby impairing initial processing efficiency. These findings highlight the capacity of neurophysiological metrics to uncover implicit aesthetic biases undetectable through traditional subjective reporting.

The enhanced P1 amplitudes observed for the Natural (N30) and Fair (Z15) foundations during early visual processing (50–140 ms) align with prior findings on the role of facial contrast in attentional prioritization. Zhang and Deng (2012) demonstrated that attractive faces elicit delayed P1 latencies in male participants, suggesting increased cognitive engagement during early visual encoding of socially salient stimuli. In the current study, the amplified P1 responses to N30 and Z15 likely reflect a similar mechanism, whereby optimized facial contrast (e.g., balanced luminance and chromaticity) enhances the perceptual fluency of facial features, thereby facilitating rapid attentional allocation. This is consistent with evolutionary perspectives positing that visual systems prioritize stimuli with higher biological relevance, such as faces with enhanced sexual dimorphism cues(Rhodes, 2006).

Winkielman et al. (2006) proposed that individuals' preference for prototypical stimuli stems from enhanced processing fluency (manifested as faster categorization speed and positive physiological responses), with fluency itself serving as a predictor of attractiveness evaluations. Our study demonstrated that Natural (N30) and Fair (Z15) foundations significantly enhanced N170 amplitudes, likely attributable to their reinforcement of contrast gradients at facial contour-feature boundaries (e.g., eye-skin and lip-skin junctions). These high-contrast configurations reduce structural parsing conflicts in the visual system (e.g., suppressing edge blur-induced feature ambiguity), thereby accelerating facial template matching and elevating processing fluency. Conversely, the Medium shade (N25), by attenuating facial contrast, suppressed N170 amplitudes and prolonged latencies—a phenomenon explained by diminished luminance contrast between facial features (e.g., eyes, lips) and surrounding skin, which forces the visual system to allocate additional resources for structural encoding. This inhibitory pattern aligns with Marzi and Viggiano's (2010) electrophysiological evidence: attractive faces elicited significantly larger N170 amplitudes (150–200 ms time window) than unattractive counterparts. Collectively, these findings indicate that foundation shades can directly modulate face-specific encoding efficacy through physical property adjustments (e.g., luminance/chromaticity tuning), with N170 amplitude serving as a neurophysiological index of optimized structural encoding efficiency.

The increase of the early posterior negativity (EPN; 200–300 ms) elicited by natural (N30) and light (Z15) foundation shades align with existing evidence linking facial attractiveness to increased EPN responses. Marzi and Viggiano (2010) demonstrated that highly attractive faces evoke larger EPN amplitudes during recognition memory tasks, reflecting prioritized attention to socially salient features and reward-related affective engagement. Similarly, Tanaka (2021) showed that red lipstick (associated with high attractiveness) elicits stronger EPN responses compared to low-attractiveness conditions (e.g., blue lipstick or no makeup), suggesting that the EPN may index late-stage affective evaluation and motivated attentional resource allocation for attractiveness. In the current study, the EPN enhancement observed with N30 and Z15 foundations may stem from their optimized luminance and chromatic contrast, which amplify the perceptual salience of facial landmarks (e.g., cheekbones, jawlines). This mechanism resonates with Werheid et al.'s(2007) "affective tagging hypothesis": Attractive faces elicit EPN enhancement in the 230–280 ms window, paralleling stimulus selection mechanisms in emotional face processing, possibly reflecting early attentional biases driven by attractiveness. Crucially, the EPN suppression induced by the natural shade (N25) mirrors the neural inefficiency observed in unattractive face processing (Wiese et al., 2014). When facial contrast is reduced by suboptimal foundation shades, the visual system struggles to integrate configural features, resulting in diminished EPN amplitudes—a marker of impaired feature binding and affective evaluation.

5. Conclusion

Neurophysiological data revealed that, despite no discernible preference differences in subjective evaluations, light (Z15) and natural (N30) foundation shades demonstrated significant advantages in capturing attention (enhanced P1 and N170 amplitudes) and evoking positive affective responses (enhanced EPN amplitudes). The comparable neural response intensities elicited by these two shades suggest a potential convergence in Chinese women's acceptance of natural tones with lighter complexions, possibly reflecting a shift from traditional "fairness-centric" ideals toward more diverse and inclusive beauty standards. In contrast, the natural shade (N25) induced neural suppression patterns (diminished EPN amplitudes) linked to impaired feature integration due to reduced facial contrast, aligning with neural inefficiency observed in unattractive face processing and reinforcing the theory of prioritized processing of socially salient features. These findings underscore the indispensable role of neurophysiological metrics in decoding implicit aesthetic biases, providing scientific guidance for the cosmetics industry to optimize formulations (e.g., balancing luminance-chromaticity contrast) and develop localized marketing strategies (e.g., emphasizing natural beauty and healthy skin tones).

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