"A Multi-Dimensional Evaluation of the Effects of Natural Scented Childcare Products on Children's Emotional Relaxation"

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1. Introduction

Olfactory neurons in humans begin to develop early in gestation, with the capacity to detect odors emerging around the 20th week of pregnancy [1]. In infants, the sense of smell plays a critical role in the formation of emotional bonds with caregivers and familiar environments, significantly influencing emotional security and attachment [2]. Maternal odors have been shown to calm crying infants, and in older children, familiar scents assist with environmental recognition and adaptation, reducing anxiety and discomfort [3]. The relationship between olfaction and emotion is particularly robust, as olfactory stimuli are known to trigger approximately 75% of human emotional responses [4]. This intimate connection arises from the overlapping neural circuits involved in both olfactory processing and emotional regulation, which are integrated within a shared neural network [5-6].

Electroencephalography (EEG) is a widely used technique in emotion research, with the EEG power spectrum divided into several frequency bands: γ (30-40 Hz), β (13-30 Hz), α (8-13 Hz), θ (4-8 Hz), and δ (0.5-4 Hz). Among these, the α and β bands are of particular interest in emotional processing studies [7]. Emotional responses, originating from brain activity, influence physiological functions such as heart rate and blood pressure through the autonomic nervous system (ANS). The ANS comprises two branches: the sympathetic nervous system (SNS), which is responsible for the "fight-or-flight" response, and the parasympathetic nervous system (PNS), which regulates the "rest-and-digest" processes [8]. These responses manifest in behavior and facial expressions.For instance, learning about an impending singing performance can elevate heart rate due to emotional tension [9]. Conversely, inhaling lavender oil has been shown to reduce heart rate and induce feelings of relaxation, highlighting the physiological impact of emotional states[10].

Both olfactory and tactile sensations are integral components of the subjective experience of cosmetic products. Previous studies have demonstrated that fragranced skincare products can modulate emotional perception and physiological responses in adults [8,11]. However, the influence of olfactory stimuli on children's emotional states remains insufficiently explored.

This study aims to establish a multi-dimensional evaluation method to quantify the effect of natural scented childcare products on children's emotion.

2. Materials and Methods

2.1 Volunteer

A total of 26 healthy volunteers, aged 9 to 12 years, participated in this study. The group included 10 males and 16 females, all of whom were students. All participants were right-handed and ensured they had at least 7 hours of adequate sleep the night before the test. On the day of testing, all volunteers self-reported no chronic or acute pain. Consumption of caffeine-containing foods and use of aromatic products were prohibited 8 hours prior to the test. Additionally, none of the volunteers had severe facial scars that could affect facial expressions.

Throughout the recruitment of volunteers and the entire research process, this study strictly adhered to the ethical guidelines of the Declaration of Helsinki by the World Medical Association (WMA). Before the study, the research protocol was reviewed and approved by the Ethics Committee of Shanghai Shengping Testing Technology Co., Ltd. (Approval No. ER24C-050), and informed consent was obtained from the volunteers and their legal guardians.

2.2 Test Product

For this study, a series of children's care products with the same fragrance were selected as test products. These included hair and body wash mousse, body cream, and face cream. Volunteers used the hair and body wash mousse for showering, applied body cream to their bodies, and face cream to their faces. The fragrance of the products combines the freshness of bergamot and limetta, the sweetness of lotus and honeysuckle, and the warmth of vetiver and musk. To ensure the safety of the product for children, allergen-free fragrance was tested. Gas chromatography-mass spectrometry (GC-MS) analysis revealed no detectable allergenic components.

2.3 Data recording and analysis

2.3.1 EEG

EEG was recorded through the Emotiv EPOC x system, which comprises 14 saline electrodes with a sampling rate of 128 Hz, as shown in Figure 1. The collected EEG signals were filtered to remove signal artifacts. A Fast Fourier Transform (FFT) was used to obtain the power values at each band. This study focuses on the α/β wave power ratio as a measure of emotional arousal. α waves are linked to calm, contemplative states, while β waves are associated with alertness. A higher α/β ratio indicates a more relaxed state [8, 12].

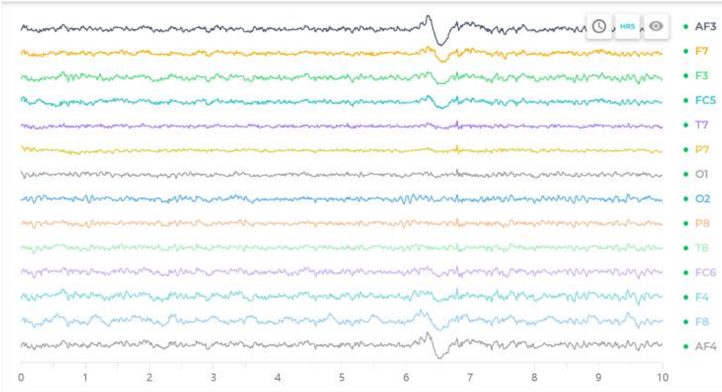

Figure 1. EEG acquisition interface.

2.3.2 ECG signals

Electrocardiogram (ECG) refers to the changes in electrical activity produced during each cardiac cycle. It is measured by a three-lead ECG sensor of the PhysioLAB physiological instrument. The heart rate can be obtained based on the RR interval of the ECG. Changes in heart rate often related to emotional arousal. Whether the emotional state is positive or negative, a higher level of emotional arousal may result in an elevated heart rate, whereas a lower degree of arousal is associated with a reduced heart rate [13].

2.3.3 Respiratory signals

The respiratory signal was monitored by the respiratory belt sensor of the PhysioLAB physiological instrument. This device uses high-sensitivity inductive technology to measure the overall displacement of the chest or abdomen, outputting parameters including respiratory rate, respiratory cycle regularity, and relative amplitude of the cycle, making it suitable for research and biofeedback applications under dynamic conditions. Studies have shown that different emotions can affect the rhythm of breathing. Deep and rapid breathing indicates the arousal of negative emotions, while emotions with high arousal levels increase the respiratory rate [14].

2.3.4 Blood pressure

Blood pressure was measured by Xiaomi Watch H1, model M2230W1. Pulse pressure is the difference between systolic and diastolic blood pressure. During exercise or stress arousal, the activity of the sympathetic nervous system intensifies, leading to increased cardiac contractility and potentially raising pulse pressure. Conversely, at rest, the heart is primarily affected by parasympathetic activity, resulting in a decrease in cardiac contractility, which may lead to a decrease in pulse pressure [15].

2.3.5 Facial expression

A camera (Lenovo Thinkplus computer model WL48A) was used to record the facial videos of volunteers during the test, and the images were analyzed by the facial expression analysis module of HRT Collection and Analysis Software (V1.6.0.3219) The module can establish a two-dimensional emotional model, with valence on the horizontal axis and arousal on the vertical axis to describe the distribution of emotions in a two-dimensional space. In this study, the dimension of emotional arousal is of interest. When individuals are in a calm and peaceful state, it corresponds to a low level of emotional arousal.

2.4 Test Process

Volunteers rest for 10 minutes before testing to calm down, then enter the testing room where staff attach monitoring devices and check for signal stability. They sit still for 5 minutes, followed by a 30-second recording of EEG, ECG, respiratory signals, facial videos, and blood pressure measurement as the baseline (BL). After using the test products, they return to sit quietly, with all signals recorded at 5 minutes(T5min) and 10 minutes (T10min) post-sit to evaluate immediate and lasting effects. The process is detailed in Figure 2.

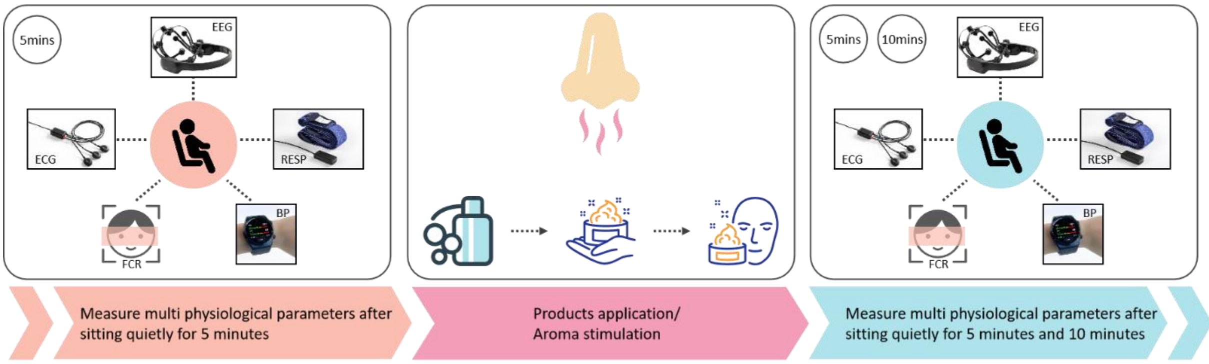

Figure 2. Test flow chart.

2.5 Statistical analysis

The difference analysis of the data is based on the normality test of the data. If the data are normally distributed, a paired-samples t-test is used, otherwise, a non-parametric test is applied. The significance level is set at 5%. The data was analyzed using SPSS 22.0 software.

3. Results

3.1 EEG parameter analysis

Human behavior, thoughts, and emotions can influence brainwave frequencies. α and β waves are considered to be most closely related to human emotions [16]. In this study, We assessed the impact of natural-scented childcare products on children's emotional states by measuring EEG and calculating the α / β power ratio. The results revealed a significant increase in the α / β power ratio at both 5 and 10 minutes post-application of the products, compared to baseline levels (Figure 3). This suggests that the use of these products induced a more relaxed brain state in the children. Notably, this relaxed brain state persisted even 10 minutes after product application, which may be attributed to the sustained fragrance of the products.

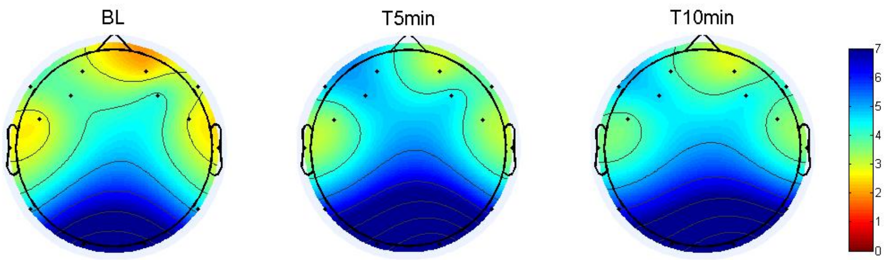

Figure 3. Changes in the brain mapping.

3.2 Heart rate analysis

Heart rate is commonly considered a biomarker of the ANS, with changes in heart rate due to non-physical activity factors believed to be associated with emotional states [13, 17]. We measured heart rate to assess the impact of natural-scented childcare products on children's emotional states. Compared to the baseline, there was a significant decrease in heart rate at 5 and 10 minutes after using the products, as shown in Figure 4. This suggests that the use of these products induced a relaxed physiological state in the children. Notably, this relaxed state persisted even 10 minutes after product application, which may be attributed to the sustained fragrance of the products. These findings imply that natural-scented childcare products can have a calming effect on children's physiological responses, potentially contributing to emotional regulation and stress reduction.

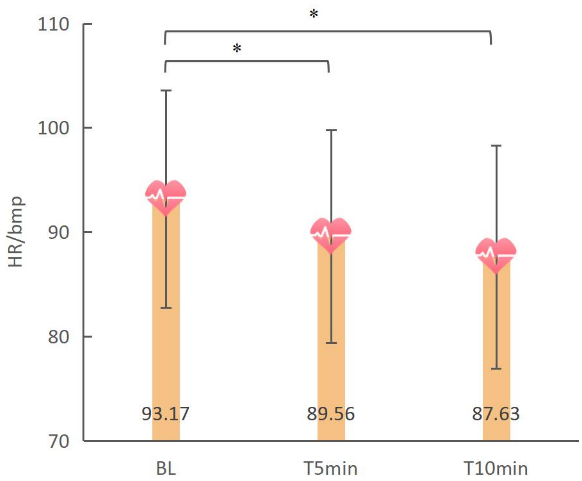

Figure 4. Changes in heart rate. Data represent means ± SD . *p value＜0.05.

3.3 Respiratory rate analysis

Spontaneous breathing is determined not only by metabolic demands but also by emotions. Breathing becomes deep and slow during leisure or relaxation, shallower and shorter when experiencing fear or anxiety, and deeper and faster when angry or excited [18-19]. The results revealed no significant change at 5 minutes post-application; however, a significant decrease was observed at 10 minutes post-application, compared to baseline levels (Figure 5). This delayed response may be attributed to the time required for the emotional effects of the product to influence respiratory patterns. These findings suggest that natural-scented childcare products can modulate children's respiratory rate, potentially contributing to emotional regulation and stress reduction.

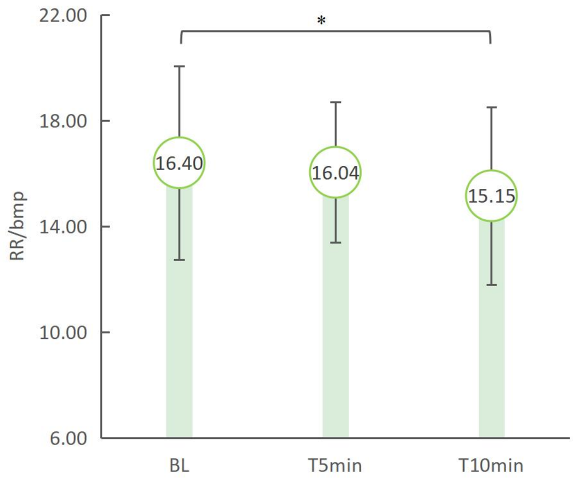

Figure 5. Changes in respiratory rate. Data represent means ± SD. *p < 0.05

3.4 Pulse pressure analysis

Studies have indicated that a state of relaxation is likely to cause a decrease in pulse pressure. Under mental and physical stress, an increase in pulse pressure is associated with the activation of physiological states controlled by the autonomic nervous system and an increase in emotional arousal [20]. In this study, we assessed the impact of natural-scented childcare products on children's emotional states by measuring pulse pressure. The results revealed no significant change at 5 minutes post-application; however, a significant decrease was observed at 10 minutes post-application, compared to baseline levels (Figure 6). When child volunteers use a wristband blood pressure monitor to measure blood pressure, it is challenging to achieve and maintain the correct posture. This difficulty may account for the lack of significant changes in pulse pressure observed at five minutes after application.

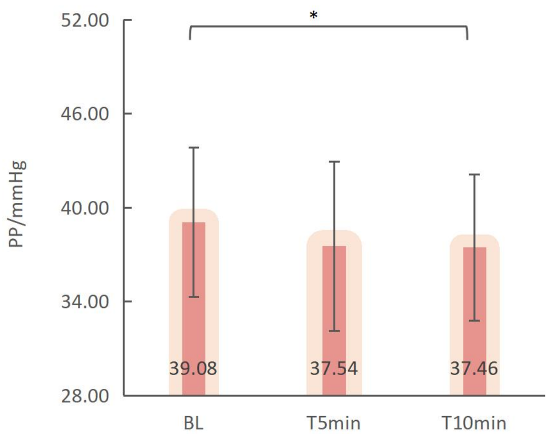

Figure 6. Changes in pulse pressure. Data represent means ± SD. *p value＜0.05.

3.5 Facial expression analysis

Compared to the baseline, volunteers showed a downward trend in emotional arousal at 5 and 10 minutes post - application (Figure 7), but the changes were not statistically significant.

Facial expression recognition systems are usually trained on adult features, which differ from children's. Children may also not have fully mastered subtle adult expressions, further increasing the difficulty of accurately interpreting children's emotions.

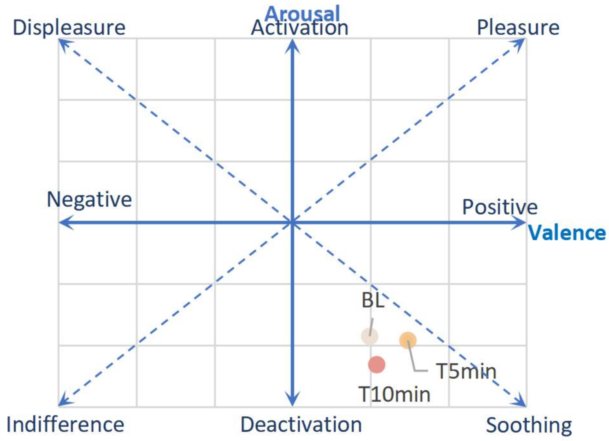

Figure 7. Two-dimensional changes in emotion

4. Discussion

Given the well-established link between olfaction and emotional processing [21], the fragrance of the product likely serves as a primary stimulus eliciting the observed emotional responses.This study established a multi-dimensional evaluation method integrating brain activity, ANS activity, and behavioral measurements to assess children's emotional responses to naturally scented childcare products. This approach offers a novel perspective for emotional research in scented childcare products. The non-invasive and portable nature of the instruments aligns with child-friendly testing protocols. Moreover, in contexts where children's self-assessment abilities are limited, this method provides objective quantitative data, compensating for the lack of self-expression. Consequently, it serves as an effective auxiliary tool for future research on the emotional impact of cosmetics on children.

The results revealed a significant increase in the α/β power ratio and a significant decrease in heart rate at 5 minutes after using the products. At 10 minutes post-application, the α/β power ratio increased significantly, and significant reductions in heart rate, respiratory rate, and pulse pressure were observed. These findings suggest that the natural-scented childcare products induced a relaxed physiological state in children, with the effects persisting even 10 minutes after application.These findings are consistent with existing literature, which has identified the α/β brainwave power ratio [14] and heart rate as sensitive indicators of emotional relaxation.

Facial expression analysis did not detect significant emotional changes at either 5 or 10 minutes post-application. This discrepancy may be attributed to several factors. First, as a non-contact assessment method, facial expression analysis may exhibit reduced sensitivity compared to contact-based physiological measurements. The Facereader system, as demonstrated by Höfling et al. [22], exhibited lower sensitivity and specificity in measuring emotional valence and arousal compared to established psychophysiological indicators such as facial electromyography and skin conductance. Second, the developmental trajectory of emotion recognition in children may influence the efficacy of facial expression analysis systems. The sensitivity to subtle emotional expressions increases with age[23], which may explain the limited sensitivity of facial expression analysis systems in younger children.

Furthermore, the use of wrist blood pressure monitors in children may introduce measurement errors if the wrist is not positioned right, as maintaining this position can be challenging for young participants. This difficulty in achieving and sustaining the correct posture could explain the absence of significant changes in pulse pressure observed at 5 minutes post-application.

In future studies, the integration of more advanced facial expression analysis systems, possibly incorporating artificial intelligence and machine learning techniques, may enhance the sensitivity and accuracy of emotional assessments in children. Additionally, the development of more child-friendly monitoring equipment that minimizes movement artifacts and improves data accuracy will be crucial. These advancements will contribute to a more comprehensive understanding of the emotional effects of childcare products on children.

5. Conclusion

This study introduces a novel multi-dimensional evaluation method that combines brain activity, ANS activity, and behavioral measurements to assess children's emotional responses to naturally scented childcare products. The findings demonstrate that these products can induce a relaxed physiological state in children, as evidenced by significant changes in α/β brainwave ratios, heart rate, respiratory rate, and pulse pressure. While facial expression analysis did not detect significant emotional changes, the physiological data provide objective evidence of the products' calming effects. This approach offers a valuable tool for future research on the emotional impact of cosmetics on children and may inform the development of child-friendly products that promote emotional well-being.

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