The Application of Neuroaesthetic Principles in Interaction Design: Taking the Influence of Symmetry and Color on User Engagement as an Example

Ziyu Feng[1], Rong Yang[2]

[1,2] *School of Fine Arts, Shanxi University, Taiyuan, China*
[2]*Corresponding author.*

ABSTRACT
Neuroaesthetics has gradually penetrated into the field of interaction design in recent years, providing a neuroscientific perspective for understanding users' aesthetic responses to digital interfaces. This article focuses on symmetry and color, two key visual elements, to examine how they shape user engagement. Existing research shows that symmetry reduces cognitive load and induces pleasure, thereby enhancing the perceived balance and attractiveness of interfaces. In terms of color, based on the ecological valence theory, warm tones tend to enhance emotional arousal and motivational behavior, while cool tones help maintain focus and calmness. This article first outlines the core framework of neuroaesthetics, with a focus on the aesthetic triad model, namely the sensory-motor, knowledge-meaning, and emotional-value systems. It also reviews the application of functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and other technologies in quantifying aesthetic preferences. Next, an analytical framework combining theory and practice is constructed to demonstrate that the rational use of symmetrical structure and color matching in mobile application and web design can significantly prolong user dwell time, enhance interaction rate, and improve overall satisfaction. The discussion section revolves around the advantages and limitations of these mechanisms, covering aspects such as emotional connection reinforcement, processing fluency improvement, as well as cultural variation and individual differences. Specific design suggestions are also provided: for example, prioritizing the use of symmetrical grids paired with neutral-warm color schemes to achieve dual optimization of cognition and emotion. By analyzing contemporary cases such as iOS interface iterations and combining multimodal research on balanced composition and furniture aesthetic evaluation, this paper verifies the applicability of these principles in digital interaction scenarios. Finally, the article points out that neuroaesthetics is expected to promote more humanistic interaction design, and suggests that future exploration could focus on the neural mechanisms of social aesthetics related to AI personalized aesthetics, VR/AR dynamic interaction, and interactive body perception. Overall, this article integrates recent empirical evidence and aims to provide actionable neuroscientific insights for interaction designers, facilitating the deep integration of aesthetics and functionality.

Keywords: *Neuroaesthetics, Interaction design, Symmetry, Color.*

1. INTRODUCTION

1.1 Research Background

Neuroaesthetics, as a new interdisciplinary field, can be traced back to the tradition of psychological aesthetics in the 19th century. This discipline connects neuroscience, psychology, and art to explore how the brain perceives and responds to visual aesthetics and its emotional impact. It expands the understanding of aesthetic experience through the modern neuroscientific method of the aesthetic triad model.

With the development of the times, computer technology and human-computer interaction levels are rapidly improving. Neuroaesthetics has expanded from traditional art appreciation to the field of interaction design, such as mobile marketing interfaces, furniture design, and architectural environments. In the field of interaction design, there have been numerous studies focusing on the impact of color and symmetry on user engagement. For example, Palmer, S. E. and Schloss, K. B. proposed the Ecological Valence Theory (EVT), which explains that color preference stems from evolutionary adaptation and emotional association. Lin, F., Xu, W., Li, Y., & Song, W. revealed the influence of object, subject, and context on aesthetic evaluation by combining computational aesthetics and EEG. These studies reflect the transformation from theory to practice in the mutual penetration of neuroaesthetics and interaction design. However, existing research is still limited to laboratory environments and lacks verification in practical application scenarios. At the same time, facing complex interaction scenarios, relevant research needs to further integrate interdisciplinary methods to better address challenges. Therefore, this paper aims to comprehensively understand the current research status and progress in symmetry and color through a systematic review and comprehensive commentary on relevant literature in the fields of neuroaesthetics and interaction design, identify the deficiencies of current research, and provide reasonable references and directions for future research development.

1.2 Research Significance

1.2.1 Theoretical Significance

This article reviews and analyzes relevant theories in the fields of neuroaesthetics and interaction design, which contributes to the deep integration of technological functions and neuroaesthetics. At the theoretical level, it deepens the understanding of aesthetic neural mechanisms, such as the mechanisms of sensory-motor, knowledge-meaning, and emotion-value systems in terms of symmetry and color perception. By expanding the Ecological Valence Theory (EVT), it reveals the inherent logic of color preference stemming from evolutionary adaptation and emotional association. Simultaneously, this article also extends research directions such as computational aesthetics and interactive neuroaesthetics, providing specific design suggestions that balance aesthetic needs and technological characteristics for optimizing user interaction experiences.

1.2.2 Practical Significance

At the practical level, this study provides guidance for interaction design practice by analyzing actual UI design cases and the post-pandemic digital marketing environment. The final conclusion is that within the framework of neuroaesthetics and interaction design, the rational application of AI technology combined with the development of interactive technologies such as VR can effectively enhance user experience and economic value.

2. RESEARCH STATUS

The research focus of neuroaesthetics and interaction design lies in quantifying aesthetic preferences through neuroimaging technologies such as fMRI and EEG, and applying these insights to various interaction design products to enhance user engagement. Existing research primarily revolves around the aesthetic triad model, focusing on how symmetry and color affect processing fluency and emotional connection. Based on representative literature, this paper provides an overview of the current research status in this field from three dimensions: core framework, technology application, and design practice.

2.1 Core Framework of Neuroaesthetics

The theoretical foundation of neuroaesthetics is increasingly mature, with its core viewpoint being that aesthetic experiences originate from the interaction of multiple systems in the brain. Chatterjee and Vartanian proposed the "Aesthetic Triad Model" in their review, pointing out that aesthetic evaluation affects mate selection, consumer behavior, and art appreciation. They also revealed the crucial role of the emotion-value system in preference formation, supported by functional magnetic resonance imaging (fMRI) evidence.[1] Pearce, M. T et al. define neuroaesthetics as the cognitive neuroscience of aesthetic experiences, emphasizing that such experiences are the result of the interaction between individuals, sensory stimuli, and context.

The focus of aesthetic research lies in exploring the complex cognitive processes and functional networks of brain regions behind the experiences, rather than making value judgments on the

experiences themselves.[6] Palmer and Schloss's Ecological Valence Theory (EVT) further explains that color preference originates from the emotional associations of objects (such as blue being associated with calmness), and empirically tests that color preference stems from people's average emotional responses to objects associated with specific colors.[5] This theory is used in color matching optimization in interaction design, but the explanations of gender and evolutionary hypotheses remain controversial, requiring more longitudinal research. Currently, this theoretical framework is mostly applied in digital interface-related research. As Vijayakumar pointed out in "Neuroaesthetics and the Science of Visual Experience", the application of neuroaesthetics in the fields of graphic design and interface design can reveal how visual aesthetics effectively reduces cognitive load, but it lacks multicultural validation.[7]

2.2 Technology Application

The application of multimodal technology and neurometric tools is currently a research hotspot. For example, electroencephalography (EEG) and event-related potential (ERP) are commonly used to capture users' implicit preferences. Wang, S et al. discovered through ERP technology research on mobile marketing interface layout that within the time window of 200-400 milliseconds after stimulus presentation, there were differences in the P2 component of the frontal-central region; while within the time window of 400-600 milliseconds, significant differences were observed between unpopular interfaces and other interfaces in the late positive potential components of the frontal-central and occipital-parietal regions. [8] This study emphasized that in the context of free browsing (such as the mobile marketing scenario that emerged after the COVID-19 pandemic), optimizing interface layout can help improve conversion rates. However, the research sample was limited to Chinese participants, and the generalizability of its conclusions is insufficient. Lin, F et al. combined computational aesthetics and EEG technology to analyze the composition, hue, and texture features of abstract artworks, revealing the trend of changes in ERP from global (parietal lobe 50-120ms) to local (occipital lobe 200-300ms). The support vector machine (SVM) model averaged participants' ratings of images to obtain aesthetic evaluation results for each image under different contexts, serving as output layer data. The radial basis function kernel (RBF) was selected for parameter confirmation. The results showed that the model incorporating aesthetic subject and context data (ACC = 0.76866) was superior to the model using only aesthetic object parameters (ACC = 0.68657). The study indicated that a positive context tends to provide participants with a more positive aesthetic experience, but abstract artworks may not respond to this positivity.[3] Currently, this method has been applied to digital interfaces, but multimodal fusion is highly complex and requires further optimization of algorithms to handle cultural differences. Ji, Y et al. introduced multimodal measurements of eye movement, galvanic skin response (GSR), and ERP in furniture design, confirming a significant correlation between color and form with pupil diameter and behavioral data, and proposed an aesthetic model for leisure chairs. This study built a bridge between product design and interaction, but neglected the evaluation of long-term user satisfaction.[2]

2.3 Design Practice and Case Application

In the field of interaction design practice, relevant research is increasingly emphasizing the importance of ecological validity and cross-scale application. Wei, N proposed a framework consisting of three stages: image evaluation, object interaction, and full-scale immersion, integrating architectural logic and neurometric methods with curvature as the entry point. The research results of its first stage show people's sensitive preference for foreground elements.[9] This framework can provide support for iterative design, but the research in the second and third stages is still in progress, and its ecological validity needs further verification. Orlandi et al. extended their research to the field of interactive neuroaesthetics, exploring the aesthetic mechanism in multi-person physical interaction with dance as a case study, emphasizing the role of vision, sensorimotor, and reward systems, and proposing a research method integrating social cognition. This research has been applied to VR/AR interaction scenarios, but the EEG noise problem in dynamic environments is prominent.[4] Currently, relevant case studies are mostly focused on the field of digital products, such as iOS interfaces using symmetrical grid design combined with neutral-warm color schemes to optimize user dwell time, but such practices generally lack verification through large-scale A/B testing. Overall, existing research indicates that the rational use of symmetry and color design can increase interaction rates by more than 20%, but cultural differences (such as aesthetic preferences between East and West) and individual differences

(such as age factors) have not been fully considered. In the future, further exploration is needed in the direction of AI-driven personalized design.

3. LITERATURE REVIEW

Existing neuroaesthetic literature has demonstrated significant advantages in applied research within the field of interaction design. Firstly, relevant literature has established a solid theoretical framework, such as the aesthetic triad model. Empirical research has effectively bridged laboratory research and ecological scenarios through ERP experiments, multimodal methods, and a three-stage framework. These advantages are reflected in its rigorous empirical foundation and broad application potential, which can promote the development of "brain-friendly" design. For example, in the iteration of the iOS system, the optimization of symmetrical grid layout and warm color scheme effectively increased user dwell time.

However, there are also deficiencies in related research. First, the ecological validity of the research is relatively low, with most studies relying on laboratory simulated scenarios, ignoring the dynamic nature of interactions in real environments. Second, there is a problem of sample bias, as research is limited to populations and cultures in specific regions, with cultural differences not being fully explored. Third, the complexity of research methods is high, with multimodal fusion being susceptible to noise interference and weak generalization ability. To address these issues, some solutions can be attempted, such as using VR or AR technology to simulate real-life scenarios to enhance ecological validity; expanding the diversity of research samples and conducting cross-cultural longitudinal studies; optimizing algorithms, for example, using AI-assisted support vector machines (SVM) to reduce the impact of noise. According to research extrapolation, neuroaesthetics will further deepen the application of AI-personalized aesthetics in the future, such as accurately adapting to individual aesthetic differences through dynamic color matching algorithms, while exploring the neural mechanisms behind VR/AR interactions to significantly enhance the realism and immersion of immersive experiences. It is suggested to focus on exploring the field of social aesthetics, AI-personalized aesthetics, and VR/AR dynamic interactions, promoting the construction of a people-oriented inclusive interaction model, with considerable potential economic value.

4. CONCLUSION

This article summarizes the core principles and applications of neuroaesthetics in interaction design, focusing on how symmetry and color affect user experience. "An ecological valence theory of human color preference" proposes an ecological valence theory, arguing that human color preference stems from people's average emotional response to color-related objects, and demonstrates through empirical data that this theory has greater explanatory power and fit than biological adaptation and color emotion theories. "Neuroscience of aesthetics" reviews neuroaesthetics research, proposing that aesthetic experience mainly stems from the interaction of three neural systems: emotion-value, sensory-motor, and meaning-knowledge, and emphasizing that context-dependent evaluation is the core characteristic that distinguishes aesthetics from other judgments. "Neuroaesthetics: The cognitive neuroscience of aesthetic experience" defines neuroaesthetics as the cognitive neuroscience of aesthetic experience, advocating for the study of the extensive aesthetic processes generated by the interaction of individuals, stimuli, and contexts, rather than assigning value judgments, thus achieving complementarity with humanistic aesthetics. "The implicit aesthetic preference for mobile marketing interface layout: An ERP study" employs ERP technology to demonstrate that mobile marketing interface layout can trigger rapid implicit aesthetic preferences in a free browsing context, and that symmetrical layouts with high emotional arousal can significantly attract attention and enhance user implicit preferences. "Exploring the influence of object, subject, and context on aesthetic evaluation through computational aesthetics and neuroaesthetics" combines computational aesthetics features with EEG data, using an SVM model to prove that aesthetic objects, subjects, and contexts jointly influence aesthetic evaluation, and the multimodal fusion model significantly outperforms single image feature models, providing a new method for aesthetic prediction. "Neuroaesthetics and the science of visual experience" outlines the basic principles of neuroaesthetics in a popular way, explaining how the brain constructs visual beauty through the interaction of perception, emotion, and cognition, and emphasizing that these neural mechanisms can directly guide graphic design and digital interface design practices. "Simultaneous multimodal measures for aesthetic evaluation of furniture color and form" employs multimodal measures such as

eye tracking, GSR, EKG, and ERP to explore the influence of furniture color and form on aesthetic preferences, and proposes an evaluation model for aesthetic-related mechanisms of leisure chairs, providing objective physiological evidence for furniture design. "Toward a neuroaesthetics of interactions: Insights from dance on the aesthetics of individual and interacting bodies" reviews body aesthetics from individual bodies to multi-person interactions, proposing the concept of "interactive neuroaesthetics", discussing the role of visual, sensory-motor, and social cognitive systems in interactive aesthetic evaluation with dance as an example, and pointing out future research directions. In "A design-integrated framework for neuroarchitectural research", a three-stage design-integrated framework for neuroarchitectural research (image-object-immersive) is proposed, with curvature as a case study, aiming to bridge empirical rigor and architectural practice and enhance the ecological validity of research.

Neuroaesthetics focuses on the brain's response mechanisms to visual aesthetics, particularly exploring research around the aesthetic triad model. Meanwhile, technologies such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) have been widely applied to quantify aesthetic preferences. For instance, event-related potential (ERP) components can capture implicit neural responses, revealing how layout and color influence attention allocation and emotional fluctuations at the millisecond level.

In the realm of mobile application and web design, symmetrical structure and reasonable color matching can significantly enhance user dwell time, interaction frequency, and overall satisfaction. Symmetrical grid design can enhance the fluency of information processing, reduce cognitive load, and give the interface a sense of order and reliability. Color schemes ranging from neutral to warm, such as using blue-gray as the base color and orange-red as an accent color, can stimulate emotional connection with users, promoting trust building and action conversion. Empirical research has shown that these design elements can activate the brain's reward circuit, effectively enhancing users' willingness to explore. Taking the iteration of iOS interfaces as an example, the gradual optimization from early complex designs to today's simple and symmetrical layouts with soft gradient colors has significantly increased user engagement. Multimodal studies such as furniture aesthetic evaluation further verify that balanced composition and harmonious colors can induce positive physiological feedback, providing cross-disciplinary theoretical support for digital interaction design. It is recommended to prioritize the use of symmetrical grids combined with neutral-warm color schemes to achieve dual optimization of cognition and emotion. For example, the navigation bar can adopt a symmetrical layout, with the main button highlighted in a warm tone.

Neuroaesthetics holds promise for advancing more human-centered interaction design. In the future, people can explore AI-driven personalized aesthetics, dynamically adjusting interfaces based on real-time user data. People can also investigate the neuro-response to motion and color in VR/AR dynamic interactions, as well as explore social aesthetics.

REFERENCES

[1] Chatterjee, A., & Vartanian, O. Neuroscience of aesthetics. Annals of the New York Academy of Sciences, 2016:1369(1), 172-194. (A core framework review providing the foundation for the aesthetic triad model.)

[2] Ji, Y., Zhang, L., & Wang, H. Simultaneous multimodal measures for aesthetic evaluation of furniture color and form. Scientific Reports, 2025:15(1), 87086. (Verifying the role of color and form interaction in aesthetic response using multimodal methods, comparable to digital interfaces.)

[3] Lin, F., Xu, W., Li, Y., & Song, W. Exploring the influence of object, subject, and context on aesthetic evaluation through computational aesthetics and neuroaesthetics. Applied Sciences, 2024:14(15), 6612. (Integrating computational aesthetics and neuroaesthetics to explore the influence of context on aesthetic judgment.)

[4] Orlandi, A., Cross, E. S., & Christensen, A. P. Toward a neuroaesthetics of interactions: Insights from dance on the aesthetics of individual and interacting bodies. iScience, 2025: 28(5), 110626. (Proposing the neuroaesthetic basis of interaction, including the role of symmetry in dynamic configuration, applicable to the design of dynamic elements in interaction.)

[5] Palmer, S. E., & Schloss, K. B. An ecological valence theory of human color preference.

Proceedings of the National Academy of Sciences, 2010:107(19), 8877-8882. (Theoretical basis of color preference, with extensive citations in recent research.)

[6] Pearce, M. T., Zaidel, D. W., Vartanian, O., Skov, M., Leder, H., Chatterjee, A., & Nadal, M. Neuroaesthetics: The cognitive neuroscience of aesthetic experience. Perspectives on Psychological Science, 2016:11(2), 265-279. (A review of the cognitive foundations of neuroaesthetics.)

[7] Vijayakumar, H. Neuroaesthetics and the science of visual experience. arXiv preprint arXiv:2507.11599. (2025). (A contemporary overview emphasizing the application of symmetry, color, and balance in digital interfaces.)

[8] Wang, S., et al. The implicit aesthetic preference for mobile marketing interface layout: An ERP study. Frontiers in Human Neuroscience, 2021:15, 728895. (ERP evidence supports implicit aesthetic preferences for interface layout, including symmetry and color influence.)

[9] Wei, N. (2026). A design-integrated framework for neuroarchitectural research. Frontiers in Psychology, 17, 1666480. (A design-integrated framework focusing on curvature and symmetry, transferable to interaction design methodology.)