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

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ABSTRACT
Neuroaesthetics has gradually penetrated into the field of interaction design in recent years, providing a neuroscience perspective for understanding the aesthetic response of users to digital interfaces. This paper focuses on the two key visual elements of symmetry and color, and examines how they shape user engagement. Existing studies have shown that symmetry reduces cognitive load and triggers pleasure, thereby enhancing the perceptual balance and attractiveness of the interface. In terms of color, based on the ecological valence theory, warm colors tend to enhance emotional arousal and motivational behavior, while cold colors help to maintain concentration and calm. This paper first outlines the core framework of neuroaesthetics, focuses on the aesthetic triplet model, namely the sensory-motor, knowledge-meaning, and emotion-value systems, and reviews the application of techniques such as functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG) in quantifying aesthetic preferences. Then, an analytical framework combining theory and practice is constructed to demonstrate that in mobile application and web design, the rational use of symmetrical structure and color matching can significantly prolong the user's residence time, improve the interaction rate and overall satisfaction. The discussion part focuses on the advantages and limitations of these mechanisms, covering the enhancement of emotional connection, the improvement of processing fluency, as well as cultural variation and individual differences, and gives specific design suggestions: for example, priority should be given to the use of symmetrical grids with neutral-warm colors to achieve dual optimization of cognition and emotion. By analyzing contemporary cases such as iOS interface iteration, and combining multimodal studies such as 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 humane interaction design, and suggests that the future can be explored around the neural mechanism of AI personalized aesthetics, VR/AR dynamic interaction and social aesthetics of interactive body perception. Overall, this paper integrates recent empirical evidence to provide actionable neuroscientific insights for interaction designers and promote the deep integration of aesthetics and function.

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

1. INTRODUCTION

1.1 Research Background

As a new interdisciplinary subject, neuroaesthetics 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 beauty and its emotional impact. Through the modern neuroscience method of aesthetic triplet model, the understanding of aesthetic experience is expanded.

With the development of the times, the level of computer technology and human-computer interaction is also rapidly improving.

Neuroaesthetics has expanded from traditional art appreciation to the field of interactive design, such as mobile marketing interface, furniture design and architectural environment. In the field of interaction design, a number of studies have focused on the impact of color and symmetry on user engagement. For example, the ecological valence theory (EVT) proposed by Palmer, S. E and Schloss, K. B explains that color preference originates from evolutionary adaptation and emotional association. Lin, F, Xu, W., Li, Y., & Song, W reveals the influence of object, subject and context on aesthetic evaluation through the combination of computational aesthetics and EEG. These studies reflect the transformation from theory to practice in the process of mutual penetration of neuroaesthetics and interaction design. However, the existing research is still limited to the laboratory environment and lacks the verification of practical application scenarios. At the same time, in the face of complex interaction scenarios, relevant research needs to further integrate interdisciplinary methods to better meet the challenges. Therefore, through the systematic review and comprehensive review of the relevant literature in the field of neuroaesthetics and interaction design, this paper aims to fully understand the research status and progress of symmetry and color, identify the shortcomings of current research, and provide a reasonable reference and direction for future research and development.

1.2 Research Significance

1.2.1 Theoretical Significance

This paper sorts out and analyzes the relevant theories in the field of neuroaesthetics and interaction design, which is helpful to promote the deep integration of scientific and technological functions and neuroaesthetics. At the theoretical level, it deepens the understanding of aesthetic neural mechanisms, such as the mechanism of sensory-motion, knowledge-meaning, and emotion-value systems in symmetry and color perception. By expanding the ecological valence theory (EVT), it is revealed that color preference originates from the internal logic of evolutionary adaptation and emotional association. At the same time, this paper also extends the research directions of computational aesthetics and interactive neuroaesthetics, and provides specific design suggestions for the optimization of user interactive experience that take into account both aesthetic needs and technological characteristics.

1.2.2 Practical Significance

At the practical level, this study provides guidance for interaction design practice by analyzing the actual cases of UI design and the digital marketing environment after the epidemic. Finally, it is concluded that under the framework of neuroaesthetics and interaction design, the rational use of AI technology and the development of interactive technologies such as VR can effectively improve user experience and economic value.

2. RESEARCH STATUS

The research focus of neuroaesthetics and interaction design is to quantify aesthetic preferences by means of neuroimaging techniques such as fMRI and EEG, and apply them to various interaction design products to enhance user participation. The existing research mainly focuses on the aesthetic ternary model, focusing on how symmetry and color affect processing fluency and emotional connection. Based on the representative literature, this paper summarizes the research status in this field from three dimensions : core framework, technology application and design practice.

2.1 Core Framework of Neuroaesthetics

The theoretical basis of neuroaesthetics is becoming more and more mature, and its core idea is that aesthetic experience comes from the interaction of multiple systems in brain regions. In the review, Chatterjee and Vartanian proposed the “aesthetic triad model”, pointing out that aesthetic evaluation can affect partner selection, consumer behavior and art appreciation. With the help of functional magnetic resonance imaging (fMRI) evidence, the key role of emotion-value system in preference formation was revealed.[1] Pearce, M. T and others defined neuroaesthetics as the cognitive neuroscience of aesthetic experience, emphasizing that this experience is the result of the interaction of individual, sensory stimulation and situation. The focus of aesthetic research is to explore the complex cognitive process behind the experience and the functional network of the brain region, rather than to judge the value of the experience itself.[6] Palmer and Schloss 's ecological valence theory (EVT) further explains that color preference stems from the emotional association of objects (such as blue being associated with calm), and empirically tests that color preference stems from people's average emotional response to objects

related to specific colors.[5] This theory has been used in color matching optimization in interaction design, but the explanation of gender and evolutionary assumptions is still controversial, and more longitudinal studies are needed. 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. The empirical research effectively bridges laboratory research and ecological scenarios through ERP experiments, multimodal methods, and three-stage frameworks. These advantages are reflected in its rigorous empirical basis and broad application potential, which can promote the development of "brain-friendly" design. For example, in the iteration of iOS system, through the optimization of symmetrical grid layout and warm color system, the user's residence time is effectively improved.

However, there are also deficiencies in related research. First, the ecological validity of the research is low, most of which are laboratory simulation scenarios, ignoring the dynamics of interaction in the real environment. The second is the problem of sample bias. The research is limited to the population and culture of specific regions, and cultural differences have not been fully explored. Third, the complexity of the research method is high, multi-modal fusion is susceptible to noise interference, and the generalization ability is weak. To solve these problems, some solutions can be tried, such as using VR or AR technology to simulate real scenes to improve ecological validity, expanding the diversity of research samples and carry out cross-cultural longitudinal research, or optimizing algorithms, such as AI-assisted support vector machine (SVM), to reduce the impact of noise. According to the research, neuroaesthetics will further deepen the application of AI personalized aesthetics in the future, such as accurately adapting individual aesthetic differences through dynamic color matching algorithm, and exploring the neural mechanism behind VR/AR interaction, so as to significantly improve the sense of reality and substitution of immersive experience. It is recommended to focus on exploring the field of social aesthetics, AI personalized aesthetics and VR/AR dynamic interaction, and promote the construction of a people-oriented inclusive interaction model, which has considerable potential economic value.

4. CONCLUSION

This paper 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 the ecological valence theory, which believes that human color preference stems from people's average emotional response to color-related objects, and proves that this theory is more explanatory and fitting than biological adaptation and color emotion theory through empirical data. "Neuroscience of Aesthetics" is a review of neuroaesthetic research. It proposes that aesthetic experience is mainly derived from the interaction of three nervous systems: emotion-value, sensory-motor and meaning-knowledge, and emphasizes that context-dependent evaluation is the core feature that distinguishes aesthetics from other judgments. "Neuroaesthetics: The Cognitive Neuroscience of Aesthetic Experience" defines neuroaesthetics as the cognitive neuroscience of aesthetic experience, which advocates the study of the broad aesthetic process generated by the interaction of individual, stimulus and context, rather than giving value judgment, so as to achieve complementarity with humanistic aesthetics. "The Implicit Aesthetic Preference for Mobile Marketing Interface Layout: An ERP Study" uses ERP technology to prove that the mobile marketing interface layout can trigger rapid implicit aesthetic preference in the context of free browsing, and the symmetrical layout with high emotional arousal can significantly attract attention and enhance users' implicit preference. "Exploring the Influence of Object, Subject, and Context on Aesthetic Evaluation Through Computational Aesthetics and Neuroaesthetics" combines computational aesthetic features with EEG data, and uses the SVM model to prove that aesthetic objects, subjects, and contexts affect aesthetic evaluation together. The multi-modal fusion model is significantly better than the single image feature model, which provides a new method for aesthetic prediction. "Neuroaesthetics and the Science of Visual Experience" provides a popular overview of the basic principles of neuroaesthetics, illustrating how the brain constructs visual beauty through the interaction of perception, emotion and cognition, and emphasizing that these neural mechanisms can directly guide the practice of graphic design and digital interface design. "Simultaneous Multimodal Measures for Aesthetic Evaluation of Furniture Color and Form" uses multimodal measurements such as eye movement,

GSR, EKG and ERP to explore the influence of furniture color and form on aesthetic preference, and proposes an evaluation model of aesthetic related mechanism of leisure chairs to provide objective physiological basis for furniture design. “Toward a Neuroaesthetics of Interactions: Insights from Dance on the Aesthetics of Individual and Interacting Bodies” reviews the body aesthetics from single body to multi-person interaction, proposes the concept of “interactive neuroaesthetics”, takes dance as an example to explore the role of vision, sensory movement and social cognitive system in interactive aesthetic evaluation, and points out the future research direction. In “A Design-integrated Framework for Neuroarchitectural Research”, a design-integrated three-stage neuroarchitectural research framework (image-object-immersion) is proposed. Taking curvature as an example, it aims to bridge empirical rigor and architectural practice and improve the ecological validity of the research.

Neuroaesthetics focuses on the brain's response mechanism to visual beauty, especially around the aesthetic triplet model. At the same time, techniques such as magnetic resonance imaging (fMRI) and electroencephalogram (EEG) have been widely used to quantify aesthetic preferences. For example, event-related potential (ERP) components capture implicit neural responses that reveal how layout and color affect attention allocation and mood swings at the millisecond level.

In the field of mobile applications and web design, symmetrical structure and reasonable color matching can significantly improve users' stay time, interaction frequency and overall satisfaction. The symmetrical grid design can enhance the fluency of information processing, reduce the cognitive load, and make the interface present a sense of order and reliability. The color matching from neutral to warm, such as blue-gray as the keynote, supplemented by orange-red as the emphasis color, can stimulate the users' emotional connection and promote trust establishment and action transformation. Empirical studies have shown that these design elements can activate the reward circuit of the brain and effectively enhance the users' willingness to explore. Taking the iOS interface iteration as an example, from the early complex design to the present simple and symmetrical layout and soft gradient color, the user stickiness has been significantly improved. Multimodal studies such as furniture aesthetic evaluation further verify that balanced composition and coordinated color can induce positive feedback at the physiological level, providing cross-domain theoretical support for digital interaction design. It is recommended to give priority to the use of symmetrical grids combined with neutral-warm colors to achieve dual optimization of cognition and emotion. For example, the navigation bar has a symmetrical layout, and the main button is highlighted in warm tones.

Neuroaesthetics is expected to promote more people-oriented interaction design. In the future, we can explore AI personalized aesthetics, dynamically adjust the interface according to users' real-time data, study the neural response of motion and color in VR/AR dynamic interaction, and explore social aesthetics.

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