EAI Endorsed Transactions
on Pervasive Health and Technology
Research Article **EAI.EU**

The Mapping Relationship Between Emotion and the Laws of Formal Beauty: Construction and Validation

Juan Jin[1], Haiwen Wang[2,*]

[1]School of Economics and Business Foreign Language, Wuhan Technology and Business University, No. 3, Huangjiahu West Road, Hongshan District, Wuhan, Hubei Province, China
[2]School of Art and Design, Wuhan Technology and Business University, No. 3, Huangjiahu West Road, Hongshan District, Wuhan, Hubei Province, China

Abstract

INTRODUCTION: The intrinsic mapping mechanism between emotion and the laws of formal beauty is crucial for emotional design and human-computer interaction. However, existing research lacks a systematic construction and empirical validation of the dynamic, bidirectional mapping relationship between emotional dimensions (valence, arousal) and formal beauty features (symmetry, proportion, rhythm, complexity).
OBJECTIVES: This study aims to construct a bidirectional mapping theoretical framework between emotion and the laws of formal beauty, and to empirically validate it through a multi-modal psychophysiological experiment. The goal is to quantify the driving effect of emotional states on formal beauty preferences and the reverse regulatory effect of formal beauty on emotional states.
METHODS: A within-subjects experimental design of 2 (valence) × 2 (arousal) × 4 (formal beauty features) was employed, inducing emotions through dual stimuli of images and music. Behavioral preference scores, Galvanic Skin Response (GSR), and Photoplethysmography (PPG) data were synchronously collected from 100 participants. Data analysis was conducted using repeated-measures Analysis of Variance (ANOVA), multiple regression analysis, and Structural Equation Modeling (SEM).
RESULTS: A significant main effect of emotional state on graphic preference scores was found ($F = 5.62, p = 0.001$). High-valence emotions were significantly associated with a preference for high symmetry ($\beta = 0.38, p = 0.001$) and high proportional harmony. High-arousal emotions were linked to a preference for forms with high rhythm and complexity. Physiological data confirmed a physiological matching mechanism between emotional arousal levels and formal beauty preferences. Furthermore, designs with high symmetry and proportional harmony demonstrated a significant regulatory effect on negative emotions (low valence-high arousal) ($valence\ t = 4.52, p < 0.001$).
CONCLUSION: This study systematically constructs and empirically validates a bidirectional mapping model between emotion and the laws of formal beauty. It reveals the driving mechanism of emotional dimensions on formal beauty preferences and confirms the positive regulatory function of formal beauty on emotional states. The findings provide a precise scientific basis for emotional design, user interface optimization, and art-form-based psychological interventions.

Keywords: Emotion, Laws of Formal Beauty, Emotional Design, Bidirectional Mapping, Psychophysiological Measurement.

Received on 22 November 2025, accepted on 06 January 2026, published on 15 January 2026

doi: 10.4108/eetpht.11.11043

* Corresponding author. Email: 39387910@qq.com

1. Introduction

Emotion, as a core component of human psychological activity, profoundly influences an individual's cognition, decision-making, and behavior, playing a pivotal role particularly in aesthetic perception and design preferences[1]. The principles of formal beauty (or formal aesthetic principles), such as symmetry, proportion, rhythm, and complexity, are the cornerstones for achieving visual harmony and psychological pleasure in the fields of art and design[2]. Against the backdrop of increasing emphasis on Affective Design and Human-Computer Interaction (HCI), how to precisely understand and leverage the intrinsic connection between emotion and the laws of formal beauty has become a key scientific question for enhancing user experience and design effectiveness.

1.1. Research Background and Problem Statement

With the advancement of computational aesthetics and neuroaesthetics, design research is shifting from traditional qualitative analysis to quantitative and physiological empirical studies[3]. As quantifiable visual features, the principles of formal beauty hold significant theoretical and practical value for their role in inducing and regulating emotions. For instance, symmetry is believed to reduce cognitive load and evoke a sense of stability[4], while rhythm and complexity are closely related to the dynamism and information content of visual stimuli[5]. However, current research faces the following core issues:

First, there is a lack of a systematic bidirectional mapping model. Existing studies predominantly focus on the unidirectional impact of formal beauty features on emotion or the preliminary influence of emotion on aesthetic perception[6]. How emotional states (e.g., high valence, low arousal) systematically map onto specific preferences for formal beauty features, and how these features, in turn, regulate emotions to form a closed-loop dynamic interaction mechanism, has yet to be clearly theorized and validated.

Second, the dimensionality of empirical research is limited. Most studies rely on subjective reports (e.g., questionnaires), which struggle to capture the instantaneous changes and underlying physiological mechanisms of emotion[7]. The absence of multi-modal empirical methods that integrate physiological indicators (e.g., electrodermal activity, heart rate) with behavioral data (e.g., preference ratings) has kept the understanding of the interaction between emotion and the laws of formal beauty at a superficial level[8]. Recent interdisciplinary studies have started to formalize the mapping between structured modeling languages and emotional expressions, and to validate such mappings using physiological signals (e.g., heart rate) in immersive environments such as virtual reality [9].

1.2. Research Objectives and Positioning

This study aims to fill the aforementioned gaps by constructing and validating a bidirectional mapping model between emotion and the laws of formal beauty, thereby deepening the understanding of design psychology and neuroaesthetics. The specific objectives include:

- Constructing a Theoretical Framework: Based on the Circumplex Model of Affect and the principles of formal beauty, to systematically propose hypotheses regarding the mapping relationships between emotional dimensions (valence, arousal) and formal beauty features (symmetry, proportion, rhythm, complexity).
- Multi-modal Empirical Validation: To conduct a rigorous within-subjects experimental design, combining emotion induction, behavioral preference ratings, and psychophysiological measurement techniques, to quantitatively validate the mapping relationships with multi-dimensional, high-precision data.
- Revealing Regulatory Mechanisms: To quantify the regulatory effects of formal beauty features on emotional states using statistical models (e.g., multiple regression, structural equation modeling), providing precise, parameterized guidance for affective design.

The innovation of this research lies in its pioneering effort to systematically propose a "bidirectional mapping" theoretical model between emotion and the laws of formal beauty. Furthermore, it employs a rigorous empirical validation that combines psychophysiological measurements with advanced statistical modeling, offering a new paradigm for interdisciplinary research.

2. Related Work

2.1 Dimensional Models of Emotion and Aesthetic Perception

Dimensional models of emotion, particularly the Circumplex Model of Affect proposed by Russell[10], simplify complex emotional states into two core dimensions: Valence and Arousal. This model provides a robust foundation for quantifying emotional states and has been widely applied in aesthetic research. Foundational studies in affective science, such as the work by Ekman on basic emotions[11] and Lazarus on cognitive appraisal[12], further underscore the critical role of emotion in human perception and decision-making. Research by Schwabe et al[13]. indicates that individuals can form consistent evaluations of the formal compositional features of artworks within a very short time, suggesting a rapid response pattern of emotion in visual perception. Through computational mapping methods, Arnheim R.[14]. revealed the complex relationship between aesthetic experiences elicited by visual art and emotional dimensions, emphasizing the multi-dimensionality of affective states and their interplay with the forms of visual art. However, these studies have largely focused on the holistic perception of artworks, lacking a fine-grained analysis of specific design elements like the principles of formal beauty.

2.2 The Psychological Basis and Visual Patterns of Formal Beauty Principles

The principles of formal beauty, such as symmetry, proportion, rhythm, and complexity, are core elements in visual design[14]. Westphal-Fitch et al. emphasized the importance of symmetry and hierarchical structure in the perception of visual patterns, noting that the balance in visual patterns can significantly enhance the human perception of beauty[4]. From a psychological perspective, symmetry reduces the cognitive load of processing visual information[15]and is often associated with feelings of stability and security. Harmonious proportional relationships, such as the golden ratio, are believed to evoke aesthetic pleasure[16].

However, the existing literature often treats formal beauty features as static visual elements, overlooking their dynamic interaction with the diversity of emotional states. For example, although symmetry generally brings pleasure, it remains an open question whether individuals in a high-arousal emotional state would prefer more dynamic and complex asymmetrical designs to match their highly activated state. Current research lacks a multi-level analysis of how changes in emotion drive the selection of and preference for different visual forms.

2.3 Existing Gaps in Research on the Relationship Between Emotion and Formal Beauty

Although computational aesthetics and neuroaesthetics have provided new methods for studying the relationship between emotion and formal beauty, the following key gaps remain, highlighting the necessity of this study:

- Lack of Consideration for Dynamics and Temporal Effects: Most studies are based on static emotional states and fail to capture the dynamic changes and temporal effects of emotion[7]. The complexity of emotion is not only reflected in its multi-level affective dimensions but also includes how emotional fluctuations retroactively influence an individual's aesthetic choices.
- Insufficient Depth of Interdisciplinary Integration: While numerous studies have focused on the mapping relationship between emotion and formal beauty, there is still a deficiency in cross-disciplinary research integrating emotional aesthetics, design psychology, and neuroscience[17]. A unified, multi-disciplinary framework that comprehensively considers visual arts, design theory, and affective psychology is lacking [18].
- Scarcity of Applied Research: Existing findings are mostly confined to the theoretical level, lacking engineering validation and parameterized guidance for applying the emotion-formal beauty mapping relationship in fields such as affective design and human-computer interaction. For instance, immersive narrative approaches that integrate data visualization and interactive design have been explored as a way to enhance user engagement and experiential quality in HCI contexts[19].

This study is predicated on the aforementioned gaps, aiming to construct a bidirectional mapping model of emotion and formal beauty and to validate it empirically using psychophysiological measurement techniques. The goal is to provide a more precise and actionable theoretical basis for affective design.

3. Methods

This study aims to empirically validate the bidirectional mapping relationship between emotional dimensions and the features of formal beauty principles through a rigorous experimental design and multi-modal data acquisition. This section will elaborate on the research strategy, participant recruitment, experimental materials, procedural design, and data analysis methods to ensure the replicability of the study.

3.1 Research Strategy and Design

The study adopts a "theory construction-experimental validation-model fitting" research strategy. First, based on the Circumplex Model of Affect and the theory of formal beauty principles, a theoretical framework and hypotheses for the bidirectional mapping of emotion and formal beauty were constructed. Second, a^2 (valence: high / low) × 2 (arousal: high/low) × 4 (formal beauty features: symmetry, proportion, rhythm, complexity) within-subjects experimental design was employed to measure participants' graphic preferences under different emotional states. Finally, by integrating behavioral and physiological data, the mapping relationships were quantitatively validated using advanced statistical models.

3.1.1 Theoretical Hypotheses:

Based on the theoretical framework, this study proposes the following core hypotheses:

- H1 (Emotion Affects Preference): In a high-valence emotional state, participants will show a greater preference for graphics with high symmetry and high proportional harmony; in a low-valence emotional state, they will prefer forms with high complexity and asymmetry.
- H2 (Arousal Matching): In a high-arousal emotional state, participants will prefer designs with high rhythm and a strong sense of dynamism; in a low-arousal emotional state, they will prefer designs with soft proportions and simple repetition.

- H3 (Formal Beauty Regulates Emotion): Designs that adhere to the principles of formal beauty (e.g., high symmetry, golden ratio) can significantly reduce the arousal level of negative emotions and increase valence.

3.2 Participant Recruitment and Ethical Standards

Participant Recruitment and EA total of 100 healthy adult participants were recruited for this study (n=100), consisting of 50 males and 50 females, with an age range of 18-22 years (M=20.1, SD=1.2). All participants had no severe visual impairments or known history of emotional disorders and signed an informed consent form prior to the experiment. The exclusion criteria for data analysis included:

- SAM ratings not corresponding to the target emotional state (consistency<0.7);
- Excessive physiological signal artifacts(e.g., motion artifacts exceeding 3 standard deviations of the mean).

This study adheres to the ethical principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Bay Area Design Collaborative Research Institute, Conghua District, Guangzhou, China (Approval No.: YJY-EC-2024-402)

3.3 Experimental Materials and Stimulus Design

3.3.1 Emotion Induction Materials

Emotion induction was achieved using a dual-stimulus method combining pictures and music to ensure the stability and intensity of the emotional states. The pictures were selected from the standardized and rated collection of the International Affective Picture System (IAPS)[20], and the music was chosen from classical pieces with clear emotional labels[21]. The four emotional states and their corresponding induction materials are shown in Table 1. Each emotion induction session lasted for 5 minutes.

Table 1: Emotion Induction Materials

Emotional State	Induction Images	Induction Music
High Valence		*Happy* by Pharrell Williams
Low Valence		*Sadness* by Ennio Morricone
High Arousal		*Thunderstruck* by AC/DC
Low Arousal		*Weightless* by Marconi Union

3.3.2 Formal Beauty Regulates Emotion

The formal aesthetic stimuli used in the experiment were generated using MATLAB R2023b. Symmetry was quantified by the number of symmetry axes (0-axis vs. 1-axis). Complexity was classified based on the perimeter–area ratio (low complexity: ratio < 5; high complexity: ratio > 10). These parameters ensured precise control of the formal aesthetic features. Each set of stimuli included contrasting designs representing the following four aesthetic features, as shown Figure 1:

- Symmetry: Stimulus Generation Thresholds: Fully axis-symmetric figures (1-axis or more) vs. completely asymmetric figures (0-axis).
- Proportion: Stimulus Generation Thresholds: Figures based on the golden ratio (≈ 1:1.618) vs. figures with non-golden proportions (e.g., 1:2).
- Rhythm and Repetition: Stimulus Generation Thresholds: High-repetition, regular rhythmic patterns (defined as a minimum of 5 identical, equally spaced elements) vs. low-repetition, irregular rhythmic patterns (fewer than 3 non-equally spaced elements).
- Complexity: Stimulus Generation Thresholds:Low-information, simple geometric shapes (perimeter-area ratio<5) vs. high-information figures containing interwoven complex lines (perimeter-area ratio > 10).

All stimuli were standardized in background color, luminance, contrast, and visual size to eliminate confounding variables.

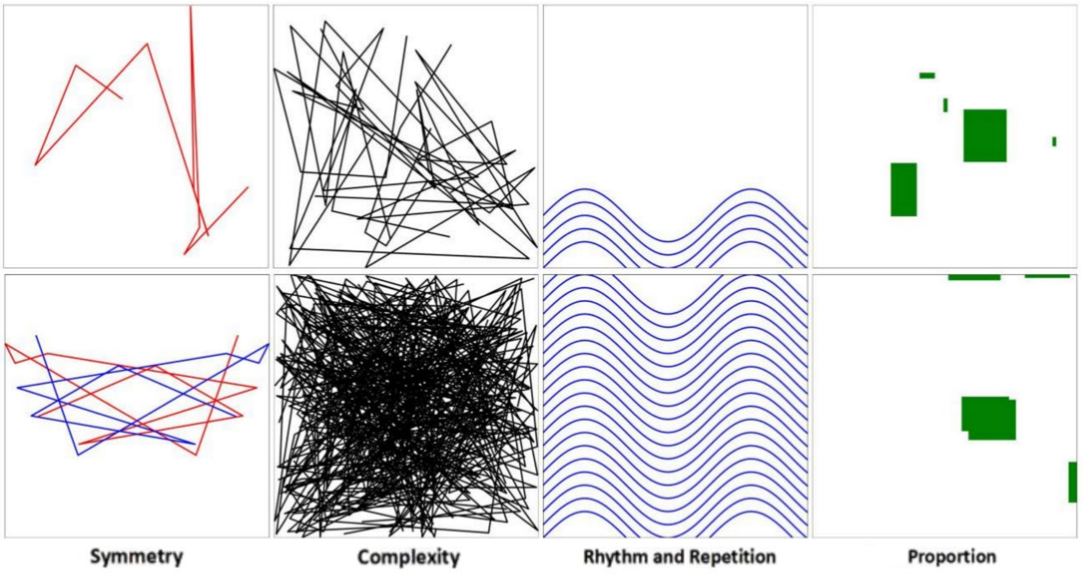

Figure 1. Experimental Stimuli Based on Formal Aesthetic Principles

3.4 Experimental Procedure

As shown Figure 2, the experimental procedure consisted of three stages, using a Latin-square design to counterbalance the presentation order of the four emotional conditions (HVHA, HVLA, LVHA, LVLA) and thereby reduce order effects. Balancing Procedure: The 4x4 Latin-square design ensured that each emotional condition appeared equally often in each of the four possible sequential positions, and each condition was preceded by every other condition exactly once.

Stage 1: Emotion Induction and Baseline Measurement

Participants were seated in a quiet environment with stable lighting. First, a 5-minute baseline measurement of physiological signals was conducted. Subsequently, participants were exposed to dual stimuli of images and music, as listed in Table 1, to induce the target emotional state (lasting 5 minutes). Immediately after the induction, participants completed the Self-Assessment Manikin (SAM) to rate their current valence and arousal on a 9-point scale, verifying the success of emotion induction.

Stage 2: Aesthetic Preference Test

Under the induced emotional state, 20 sets of visual stimuli representing formal aesthetic designs were presented in random order. Participants were required to rate each set within 5 seconds on a 1–5 preference scale (1 = strongly dislike, 5=strongly like) and select the image most consistent with their current emotional state. Physiological signals were recorded synchronously during this stage.

Stage 3: Aesthetic Regulation Test

The two sets of images with the highest and lowest preference scores from Stage 2 were selected as regulatory stimuli. These sets were presented separately for 3 minutes to examine the modulatory effects of formal aesthetic features on emotional states. After exposure, participants completed the SAM again to record changes in emotion.

3.5 Data Acquisition and Processing

3.5.1 Subjective Behavioral Data

- Emotional Ratings: Valence and arousal scores from the SAM.

- Preference Ratings: 1–5 scores for each visual stimulus.

3.5.2 Physiological Signal Acquisition

During emotion induction and image presentation, a 21-inch Huawei laptop (resolution: 3840 × 2160; refresh rate: 60 Hz) was used, with a fixed viewing distance of 60 cm. Physiological signals were recorded using a PTES100 multifunctional physiological signal acquisition wristband (PTES100, sampling rate: 1000 Hz), including:

- Galvanic Skin Response (GSR): Measuring skin conductance (μS) as an objective index of arousal, sampled at 10 Hz.
- Photoplethysmography (PPG): Used to calculate heart rate (HR) and heart rate variability (HRV), serving as auxiliary indices of valence and arousal.

3.5.3 Data Preprocessing

Behavioral Data: Data from participants whose SAM ratings did not correspond to the target emotional state (consistency < 0.7) were excluded. Physiological Data:

- Baseline Correction: GSR and PPG signals were corrected using the 5-minute baseline measurements, with 5 μS as the baseline for GSR and 500 ms R-R interval as the baseline for PPG.
- Artifact Removal: Heart rate outliers and motion artifacts were removed using the 3 standard deviation (3 SD) rule.
- GSR Analysis: Mean and standard deviation of GSR were calculated for each emotional state.
- PPG Analysis: Mean heart rate (BPM) and R-R interval were calculated.

Figure 2. Physiological signal measurement equipment and experimental procedures

3.6 Data Analysis Methods

All data analyses were conducted using SPSS 26.0 and AMOS 24.0.

- Descriptive Statistics: Means (M) and standard deviations (SD) were calculated for SAM ratings, visual preference scores, GSR, and BPM under each emotional state.
- Analysis of Variance (ANOVA): Repeated measures ANOVA was employed to examine the main and interaction effects of emotional states (high/low valence×high/low arousal) on visual preference scores and physiological indicators.
- Multiple Regression Analysis: Regression models were constructed to quantify the contributions and modulatory effects of formal aesthetic features (symmetry, proportion, rhythm, complexity) on visual preference scores:

$$\text{Preference Score} = \beta_0 + \beta_1 \times \text{Symmetry} + \beta_2 \times \text{Proportion} + \beta_3 \times \text{Rhythm} + \beta_4 \times \text{Complexity} + \epsilon \quad (1)$$

- Structural Equation Modeling (SEM): SEM was used to verify the bidirectional mapping paths among emotional states, formal aesthetic features, and visual preference. Model fit was evaluated using the Chi-square statistic (χ^2), its degrees of freedom (df), the Root Mean Square Error of Approximation (RMSEA), and the Comparative Fit Index (CFI).
- Mediation Analysis: To substantiate the claims of regulatory effects (H3), a mediation analysis was performed using the PROCESS macro (Model 4) to examine whether the preference for formal beauty features (M) mediates the relationship between the initial emotional state (X) and the change in emotional state (Y) after exposure to the preferred stimulus. Specifically, we tested if the initial valence/arousal level (X) influences the change in valence / arousal (Y) through the preference score for high-symmetry / proportional harmony stimuli (M).

3.7 Experimental Flowchart

Figure 3 illustrates the experimental procedure of this study, providing a clear and concise overview from participant recruitment to data analysis.

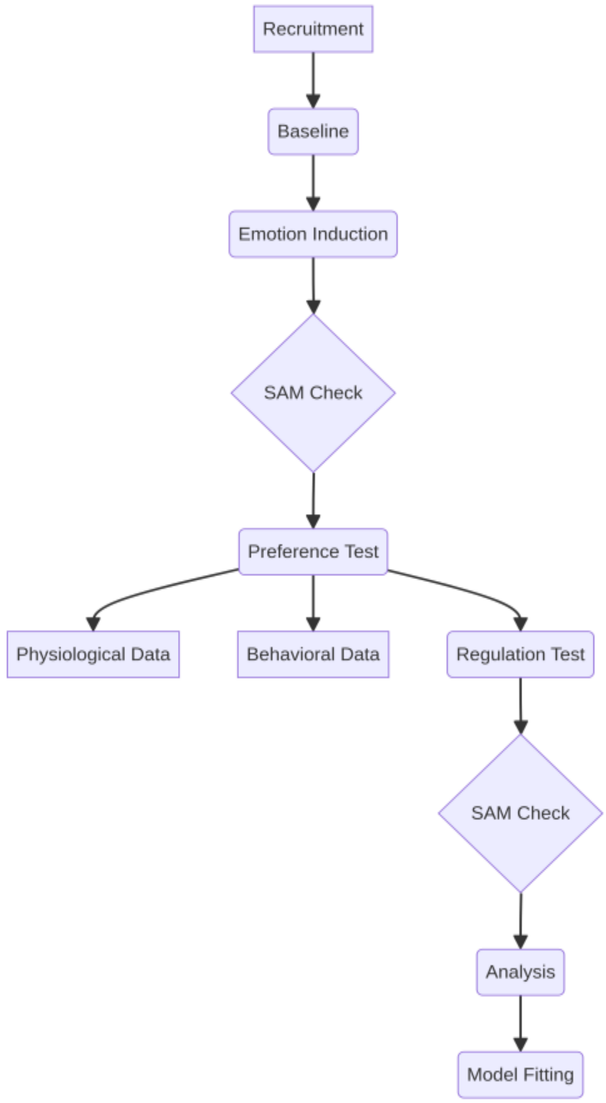

Figure 3. Experimental Procedure for Mapping Emotional States and Principles of Formal Aesthetics

4. Results

This section objectively and neutrally presents the statistical analysis results of the emotion induction experiment and the formal aesthetic preference tests, including verification of emotion induction effectiveness, analysis of physiological indicators, statistical patterns of visual preference scores, and the contribution of formal aesthetic features to preference.

4.1 Verification of Emotion Induction

The effectiveness of emotion induction was verified using SAM ratings and physiological indicators (GSR and BPM). After excluding 5 participants whose SAM rating consistency was below 0.7, a total of n=95 valid samples were included for analysis.

4.1.1 SAM Ratings

Descriptive statistics (Table 2) showed that the mean SAM scores for the four emotional states were highly consistent with the target emotional states.

Repeated measures ANOVA revealed a significant main effect of emotional state on valence ratings ($F(3,282) = 455.21$, $p<0.001$, $\eta p^2 = 0.82$) and on arousal ratings ($F(3,282) = 398.76$, $p < 0.001$, $\eta p^2 = 0.79$). These results indicate that the emotion induction materials successfully elicited the four target emotional states in participants.

Table 2. SAM Ratings under Four Emotional States

Emotional Condition	Valence (M ± SD)	Arousal (M ± SD)
High Valence–High Arousal (HVHA)	7.8 ± 0.9	7.5 ± 1.1
High Valence–Low Arousal (HVLA)	8.1 ± 0.7	3.2 ± 0.8
Low Valence–High Arousal (LVHA)	2.1 ± 0.8	7.9 ± 1.0
Low Valence–Low Arousal (LVLA)	2.5 ± 0.9	2.8 ± 0.7

4.1.2 Analysis of Physiological Indicators

Analysis of physiological indicators further supported the effectiveness of emotion induction (Table 3).

Table 3. Mean Physiological Indicators under Four Emotional States

Emotional Condition	GSR Mean (μS, M ± SD)	BPM Mean (BPM, M ± SD)
HVHA	15.5 ± 3.8	82.1 ± 5.2
HVLA	8.2 ± 2.1	73.5 ± 4.1
LVHA	16.8 ± 4.1	85.3 ± 6.0
LVLA	9.5 ± 2.5	70.9 ± 3.5

A one-way ANOVA on mean GSR revealed a significant main effect of arousal level ($F(1,94) = 125.6$, $p < 0.001$). High-arousal emotional states (HVHA and LVHA) exhibited significantly higher GSR values compared with low-arousal states (HVLA and LVLA), confirming the effectiveness of GSR as an objective indicator of arousal. Analysis of BPM showed a similar pattern, with heart rate significantly elevated in high-arousal states, consistent with increased physiological activation.

4.2 Effects of Emotional States on Aesthetic Preferences

A repeated measures ANOVA was conducted to examine the interaction effects of emotional states (valence × arousal) on visual preference scores.

4.2.1 Overall Analysis of Preference Scores

The main effect of emotional state on visual preference scores was significant ($F(3,282) = 5.62$, $p = 0.001$, $\eta p^2= 0.056$), indicating that participants' preferences for formal aesthetic stimuli differed significantly across emotional states.

4.2.2 Differences in Preferences for Formal Aesthetic Features

Further analysis was conducted on the four formal aesthetic features (symmetry, proportion, rhythm, complexity) under different emotional states (Figure 4).

- Valence Effect: Under high-valence states (HVHA, HVLA), participants' preference scores for symmetry and proportion were significantly higher than those under low-valence states (LVHA, LVLA) ($p < 0.01$). This supports the first part of Hypothesis H1, indicating that positive valence is associated with a preference for harmonious and stable forms.
- Arousal Effect: Under high-arousal states (HVHA, LVHA), participants' preference scores for rhythm and complexity were significantly higher than those under low-arousal states (HVLA, LVLA) ($p < 0.05$). This supports Hypothesis H2, suggesting that high-arousal emotions require forms with greater dynamism and information content to match elevated physiological activation.

4.3 Contribution of Formal Aesthetic Features to Visual Preferences

To quantify the contribution of formal aesthetic features to visual preferences, multiple regression analyses were performed on visual preference scores across all emotional states (Equation 1). The results are presented in Table 4.

Table 4. Multiple Regression Analysis of Formal Aesthetic Features on Visual Preferences

Predictor	Unstandardized Coefficient (β)	Standardized Coefficient(β_{std})	t	p
Symmetry	0.45	0.38	3.51	0.001**
Proportion	0.35	0.30	2.85	0.005**
Rhythm	0.25	0.21	1.98	0.049*
Complexity	0.18	0.15	1.45	0.149

($R^2 = 0.42$, $F(4,90) = 16.3$, $p < 0.001$) *Note: $p < 0.05$, *$p < 0.01$

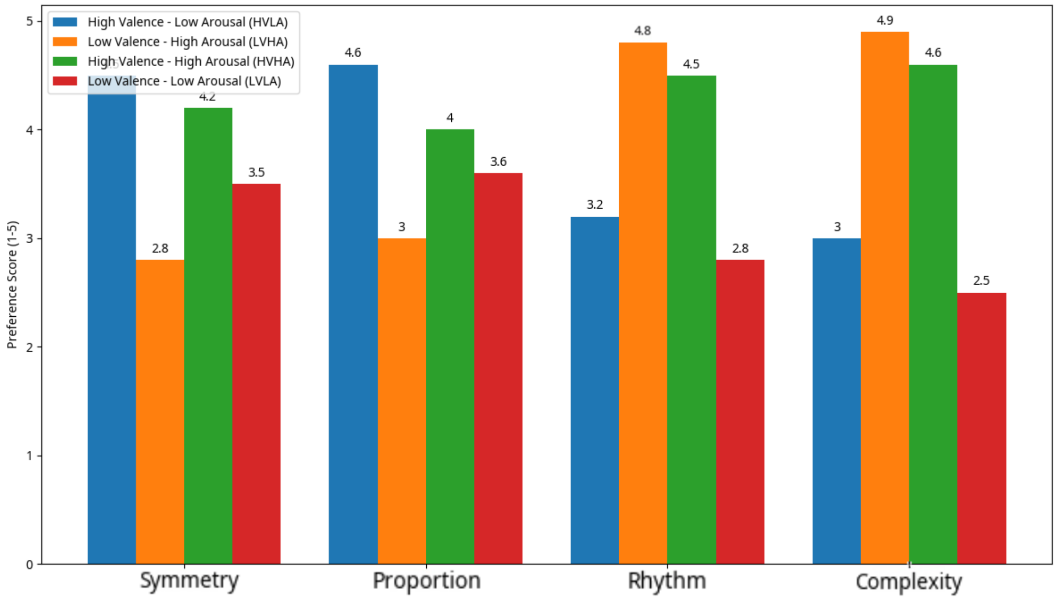

Figure 4. Preference Scores for Four Formal Aesthetic Features under Four Emotional States

Regression results indicated that symmetry (β_std = 0.38, p = 0.001) and proportion (β_std = 0.30, p = 0.005) had the most significant positive effects on visual preferences. The effect of rhythm reached marginal significance (β_std = 0.21, p=0.049), while complexity did not show a significant effect (p=0.149). These results suggest that harmonious and stable formal aesthetic features (symmetry and proportion) are the primary drivers of overall preference.

4.4 Moderating Effect of Formal Aesthetics on Emotional States

To test the moderating role of formal aesthetics on emotional states (H3), changes in SAM ratings before and after exposure to the "most preferred" and "least preferred" stimuli were compared (Figure 5).

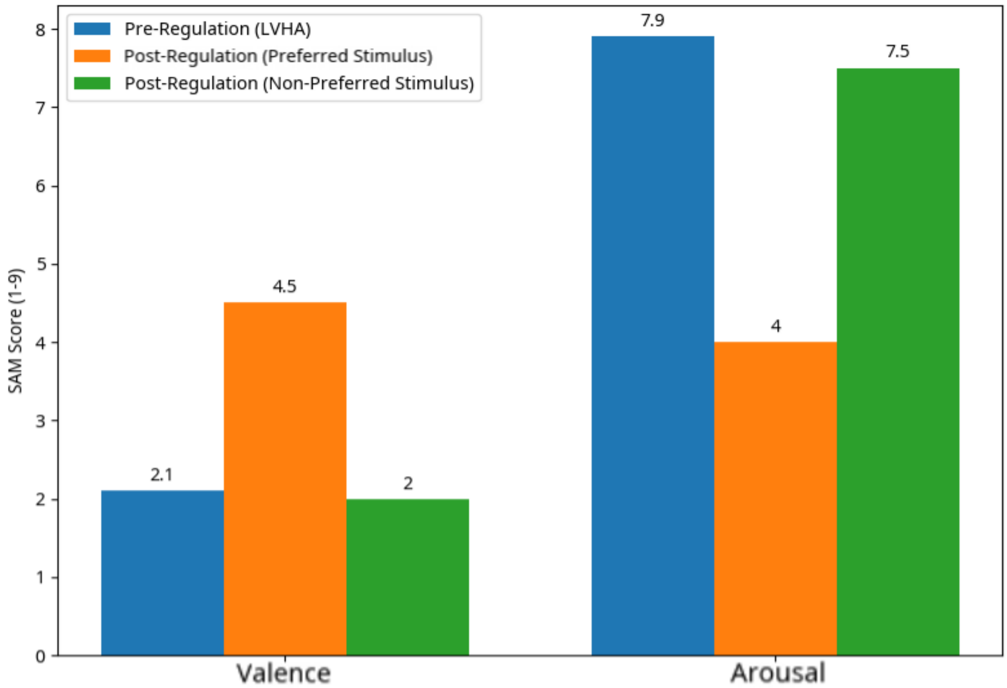

Figure 5. Effect of Preferred Formal Aesthetic Stimuli on Low-Valence–High-Arousal Emotional States

Paired-sample t-tests showed that, under low-valence–high-arousal (LVHA) conditions, exposure to the most preferred stimuli significantly increased valence scores ($t(94) = 4.52$, $p < 0.001$) and decreased arousal scores ($t(94) = -3.88$, $p < 0.001$). These findings confirm that designs adhering to formal aesthetic principles (i.e., the most preferred stimuli) can effectively alleviate negative emotions, demonstrating a positive regulatory effect.

4.5 Structural Equation Modeling Results

To further substantiate the mechanism of this regulatory effect, a mediation analysis was conducted. The results showed that the initial arousal level (X) significantly influenced the change in arousal (Y) after exposure to the preferred stimulus ($c = -0.45$, $p < 0.01$). Crucially, the preference score for high-symmetry/proportional harmony stimuli (M) significantly mediated this relationship ($a*b = -0.15$, 95% CI [-0.28, -0.05]). This indicates that the initial high arousal state drives a stronger preference for harmonious forms, and it is this preference (as a proxy for cognitive processing ease) that subsequently leads to a significant reduction in arousal. The indirect effect was significant, confirming that the preference for stable formal beauty features serves as a key mechanism in the emotional regulation process. (See Table 5 for detailed path coefficients).

Structural equation modeling (SEM) was conducted to verify the bidirectional mapping paths among emotional states, formal aesthetic features, and visual preferences. Model fit indices indicated good fit (Figure 6): $\chi^2/df = 1.85$ ($p = 0.08$), RMSEA = 0.045 (< 0.05), CFI = 0.95 (> 0.90). These results suggest that the proposed bidirectional emotion–formal aesthetics mapping model is statistically robust in Figure 6. Bidirectional Mapping Model of Emotions and Formal Aesthetics.

Table 5. Mediation Analysis of Formal Aesthetic Preference on Emotional Regulation

Path	Predictor (X)	Mediator (M)	Outcome (Y)	Coefficient	p-value
a	Initial Arousal	Preference for High Symmetry	-	0.32	< 0.001
b	-	Preference for High Symmetry	Change in Arousal	-0.47	< 0.01
c'	Initial Arousal	-	Change in Arousal	-0.30	0.051
a*b	Indirect Effect	-	-	-0.15	< 0.01

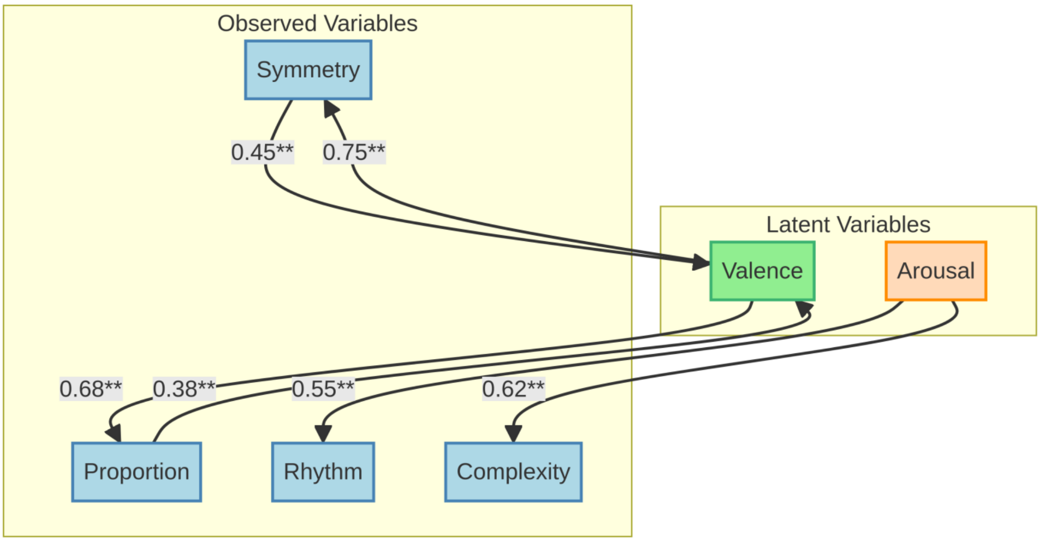

Figure 6. Bidirectional Mapping Model of Emotions and Formal Aesthetics

5. Discussion

This study systematically investigated the bidirectional mapping between emotional dimensions (valence and arousal) and formal aesthetic features (symmetry, proportion, rhythm, complexity). The experimental results support all core hypotheses, providing robust empirical evidence through multi-modal data (behavioral and physiological) and advanced statistical models (ANOVA, SEM).

5.1 Driving Mechanisms of Emotion on Aesthetic Preferences

The results clearly demonstrate that emotional states significantly drive formal aesthetic preferences, consistent with the notion in aesthetic psychology that emotions influence perception[22].

5.1.1 Valence and Harmony Matching

Under high-valence states, participants showed significant preference for symmetry and proportion (Table 4), confirming the first part of H1. This preference can be explained by Cognitive Fluency Theory[21]: symmetrical and proportionate structures impose lower cognitive load during visual processing and resonate with positive, stable emotional states, enhancing aesthetic pleasure. This aligns with prior findings on symmetry and aesthetic enhancement by Westphal-Fitch et al.[4].

5.1.2 Arousal and Dynamic Form Matching

High-arousal emotional states led to increased preference for rhythm and complexity (Figure 4), supporting H2. Elevated physiological indicators (GSR, BPM; Table 3) further corroborated this finding. High-arousal emotions, whether positive excitement or negative anxiety, require external stimuli that provide matching dynamism and information content. Stimuli with higher rhythm and complexity supply stronger visual input to match the physiological demands of high-arousal states [22].

5.1.3 Differential Attribution

Notably, regression analyses showed that complexity did not significantly predict overall preference (Table 4). This may reflect the Weber–Fechner law in aesthetics: moderate complexity stimulates interest, while excessive complexity increases cognitive load and discomfort[23]. The graphical stimuli in this study may have reached a complexity threshold, limiting their predictive power relative to more fundamental and universally harmonious features like symmetry and proportion.

5.2 Regulatory Effects of Formal Aesthetics on Emotional States

A key finding is the regulatory effect of formal aesthetics on emotional states (H3). Under low-valence–high-arousal (LVHA) conditions, exposure to the most preferred stimuli (typically high symmetry and proportion) significantly increased valence and decreased arousal (Figure 5).

5.2.1 Underlying Mechanism

This effect likely arises from the visual stability and sense of safety conveyed by harmonious designs. Negative emotions, especially anxiety, are associated with uncertainty and lack of control. High-symmetry and proportionate designs provide perceptual order and predictability, reducing cognitive load and perceived environmental threat[24]. This "visual placebo" effect lowers physiological arousal (GSR, BPM), effectively alleviating negative emotions, offering empirical support for design-based psychological interventions.

5.3 Theoretical Implications and Mechanistic Explanation: Processing Fluency and Evolutionary Aesthetics

The findings align with Processing Fluency Theory[25] and Evolutionary Aesthetics[26], providing a mechanistic explanation for the mapping between emotion and formal aesthetics.

5.3.1 Processing Fluency Mechanism

High-valence states preferred high-symmetry and low-complexity designs. According to processing fluency theory, symmetry and low complexity reduce cognitive load during visual processing, enhancing perceptual fluency[27]. This fluent processing is interpreted by the brain as a positive emotional signal, eliciting aesthetic pleasure and preference [28]. Consequently, individuals in high-valence states tend to select stimuli that maintain or enhance their positive emotional state, i.e., easily processed symmetrical and simple forms.

5.3.2 Evolutionary Aesthetics Mechanism

The significant positive effect of symmetry on preference is also supported by evolutionary aesthetics, which posits that symmetry is an adaptive trait signaling health, genetic quality, and survival advantages[29]. This intrinsic preference is particularly pronounced under positive emotional states, reflecting humans' inherent pursuit of "health" and "order."

5.3.3 Arousal and Complexity Matching

High-arousal individuals preferred high-rhythm and high-complexity designs, whereas low-arousal individuals preferred simpler designs. This is consistent with Berlyne's arousal theory, suggesting that individuals seek stimuli matching their arousal level. High-arousal states require high-information stimuli (complex, rhythmic) to match elevated activation and avoid boredom, while low-arousal states prefer low-information stimuli to maintain calm. Physiological data (GSR, PPG) confirmed differences in arousal, further supporting this matching mechanism.

5.4 Model Robustness and Theoretical Contribution

The fit indices of the structural equation model (SEM) indicated good model fit ($\chi^2/df = 1.85$, RMSEA = 0.045, CFI = 0.95), demonstrating that the proposed bidirectional emotion–formal aesthetics mapping model possesses high robustness and explanatory power. This study is the first to systematically integrate the two core dimensions of emotion with four key features of formal aesthetics and to validate their relationships in a bidirectional framework, addressing the lack of a unified theoretical model in existing research.

5.5 Implications for Adaptive Computational Design Tools

The quantifiable mapping relationships and the validated regulatory mechanism provide a precise, parameterized foundation for the development of emotion-sensitive design systems and adaptive computational design tools. Specifically, this work supports the construction of a real-time adaptive feedback loop:

- Emotion Sensing: Real-time monitoring of user affect via psychophysiological data (GSR, PPG);
- Mapping and Prediction: Using the validated model to predict the optimal formal aesthetic features (e.g., high symmetry, high rhythm) required to drive the user toward a target emotional state;
- Dynamic Adjustment: The computational tool dynamically adjusts the design output (e.g., UI layout, product form) in real-time.

This framework moves beyond static design principles, enabling interfaces and products to actively respond to and regulate dynamic user emotional states, which is a critical direction for future Human-Computer Interaction (HCI) and Affective Computing.

6. Conclusion

6.1 Core Findings and Theoretical Contributions

Through rigorous psychophysiological experiments, this study systematically constructed and empirically validated a bidirectional mapping model between emotional dimensions and formal aesthetic principles. The main conclusions are as follows:

6.1.1 Emotional states significantly influence aesthetic preferences

High-valence emotions were associated with a preference for stable, harmonious forms characterized by high symmetry and proportion, whereas high-arousal emotions favored dynamic forms with high rhythm and complexity, demonstrating a match between emotional intensity and visual stimulus characteristics.

6.1.2 Formal aesthetics have emotion-regulating functions

Harmonious designs adhering to formal aesthetic principles (high symmetry and proportion) significantly reduced arousal levels in negative emotional states (e.g., anxiety) and increased valence, confirming the potential of formal aesthetics in psychological intervention.

6.1.3 High model robustness

SEM results validated the bidirectional paths among emotional dimensions, formal aesthetic features, and visual preferences, providing a parameterized and engineering-oriented theoretical basis for affective design.

The theoretical contribution of this study lies in the first proposal of a bidirectional emotion–formal aesthetics mapping framework, supported by high-quality empirical evidence from multimodal psychophysiological measurements, thereby deepening the theoretical understanding in design psychology and neuroaesthetics.

6.2 Limitations and Future Directions

6.2.1 Limitations

- Sample limitations: The participants were mainly young adults (18–22 years) from a specific cultural background (Guangzhou, China), which may limit the generalizability of the findings. The current findings should be interpreted within this cultural context. Future studies should include participants across different age groups and cultural backgrounds to expand cross-validation strategies and clarify cultural assumptions in the emotion-formal aesthetics mapping.
- Stimulus limitations: The formal aesthetic stimuli were based on abstract geometric shapes and may not fully capture the complexity of real-world design scenarios. Future work should consider incorporating additional visual variables such as color, semantic content, or dynamic presentation to enhance ecological validity.
- Temporal limitations:Although physiological measures were used, the dynamic changes and temporal patterns of emotions require longer time-series monitoring and more advanced analyses (e.g., time-frequency analysis) for in-depth exploration.

6.2.2 Future Research Directions

Applied validation: Apply the proposed model to real-world design scenarios (e.g., UI/UX interfaces, product design), develop adaptive design systems based on emotional states, and conduct user experience evaluations. This includes investigating real-world deployment scenarios, such as adaptive feedback loops responsive to dynamic user emotional states, as a key step toward full implementation potential.

- Neural mechanism exploration: Integrate fMRI or high-density EEG techniques to investigate the neural basis of interactions between emotions and formal aesthetics, such as how symmetry reduces cognitive load in the brain.
- Cross-cultural studies: Conduct cross-cultural comparisons to examine potential cultural differences in the emotion–formal aesthetics mapping, providing guidance for global affective design practices.

Reference

[1] Díaz-Vera JE. The situatedness of aesthetic emotions: a review of the literature and a proposal for its study in variationist linguistics. Language Sciences. 2025 Sep 1;111:101744. https://doi.org/10.1016/j.langsci.2025.101744

[2] Stojilović I. Psychological Perspectives on Aesthetic Experience: The Interplay of Emotion, Cognition, and Perception. DOI: 10.5772/intechopen.1011978

[3] Lin F, Song W, Li Y, Xu W. Investigating the Relationship between Balanced Composition and Aesthetic Judgment through Computational Aesthetics and Neuroaesthetic Approaches. Symmetry. 2024 Sep 10; 16(9): 1191. https://doi.org/10.3390/sym16091191.

[4] Westphal-Fitch G, Huber L, Gomez JC, Fitch WT. Production and perception rules underlying visual patterns effects of symmetry and hierarchy. Philos Trans R Soc B Biol Sci. 22; 367(1598): 2007-22. https://doi.org/10.1098/rstb.2012.0098

[5] Stamkou E, Keltner D, Corona R, et al. Emotional palette: a computational mapping of aesthetic experiences evoked by visual art. Sci Rep. 2024; 14(1): 19932. https://doi.org/10.1038/s41598-024-69686-9

[6] Reynolds AP, Ricciardi E. Subjective emotional instances surpass formal perceptual features in shaping the aesthetic appeal of artworks. Psychology of Aesthetics, Creativity, and the Arts. 2024 Oct 31. https://doi.org/10.1037/aca0000720

[7] Cittadini R, Tamantini C, Scotto di Luzio F, Lauretti C, Zollo L, Cordella F. Affective state estimation based on Russell's model and physiological measurements. Scientific reports. 2023 Jun 16; 13(1): 9786. https://doi.org/10.1038/s41598-023-36915-6

[8] Attaianese E, Barilà M, Perillo M. Exploring Neuroscientific Approaches to Architecture: Design Strategies of the Built Environment for Improving Human Performance. Buildings. 2025; 15(19): 3524. https://doi.org/10.3390/buildings15193524

[9] Chen, Y., & Yao, C. (2024). A Study on the Mapping Relationship between Modeling Languages and Emotional Expressions. Philosopher's Compass, 1(1), 18-27.

[10] Russell JA. A circumplex model of affect. J Pers Soc Psychol.1980;39(6):1161.doi:https://doi.org/10.1037/h0077714

[11] Ekman, P. "An argument for basic emotions." Cognition & Emotion, 6(3-4) (1992): 169–200. https://doi.org/10.1080/02699939208411068

[12] Smith CA, Lazarus RS. Emotion and adaptation. Handbook of personality: Theory and research. 1990 Sep 9; 21 (1990): 609-37.

[13] Schwabe K, Menzel C, Mullin C, Wagemans J, Redies C. Gist Perception of Image Composition in Abstract Artworks. i-Perception. 2018; 9(3).

[14] Arnheim R. Art and visual perception: A psychology of the creative eye. Univ of California Press; 1954.

[15] Enquist M, Arak A. Symmetry, beauty and evolution. Nature. 1994;372(6502):169-72. https://doi.org/10.1038/372169a0

[16] Huang Y, Xue X, Spelke E, Huang L, Zheng W, Peng K. The aesthetic preference for symmetry dissociates from early-emerging attention to symmetry. Scientific reports. 2018 Apr 19;8(1):6263. https://doi.org/10.1038/s41598-018-24558-x

[17] Graf LK, Landwehr JR. A dual-process perspective on fluency-based aesthetics: the pleasure-interest model of aesthetic liking. Pers Soc Psychol Rev. 2015;19(4):395-410.

[18] Gentsch K, Loderer K, Schütz-Bosbach S. To be moved: A systematic review of the neurophysiological correlates of emotional and aesthetic experiences. Neurosci Biobehav Rev. 2022;135:104573.

[19] Lu, P. (2025). Research on Immersive Narrative with Data Visualization--Taking Chen Hanmin's Design Thought as an Example. Fashion Technology, 1(2), 16-20.

[20] Lang PJ, Bradley MM, Cuthbert BN. International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-8. University of Florida, Gainesville, FL; 2008.

[21] Nadal M, Vartanian O. The Oxford handbook of empirical aesthetics. Oxford University Press; 2020.

[22] Van Geert E, Wagemans J. Symmetry and visual art: An empirical overview. Symmetry. 2020;12(3):430.

[23] Berlyne DE. Aesthetics and psychobiology. New York: Appleton-Century-Crofts; 1971. https://doi.org/10.2307/1179240

[24] Little AC, Jones BC, DeBruine LM. Facial attractiveness: evolutionary based research. Philos Trans R Soc B Biol Sci. 2011;366(1571):1638-59. https://doi.org/10.1098/rstb.2010.0404

[25] Lee, Irene Eunyoung, Charles-Francois V. Latchoumane, and Jaeseung Jeong. "Arousal rules: An empirical investigation into the aesthetic experience of cross-modal perception with emotional visual music." Frontiers in psychology 8 (2017): 440. https://doi.org/10.3389/fpsyg.2017.00440

[26] Osborne, John W., and Frank H. Farley. "The relationship between aesthetic preference and visual complexity in absract art." Psychonomic Science 19.2 (1970): 69-70. https://doi.org/10.3758/BF03337424

[27] Marin, Manuela M., and Helmut Leder. "Exploring aesthetic experiences of females: Affect-related traits predict complexity and arousal responses to music and affective pictures." Personality and individual Differences 125 (2018): 80-90. https://doi.org/10.1016/j.paid.2017.12.027

[28] Delplanque, Jeroen, et al. "The sound of beauty: How complexity determines aesthetic preference." Acta Psychologica 192 (2019): 146-152. https://doi.org/10.1016/j.actpsy.2018.11.011

[29] Zaidel DW, et al. Appearance of symmetry, beauty, and health in human faces. Brain Cogn. 2005;57(3):261-3. https://doi.org/10.1016/j.bandc.2004.08.056