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Computer-Aided Design AND APPLICATIONS

Evaluation of Cultural Creative Product Design Based on Computer-Aided Perceptual Imagery System

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Abstract. This paper introduces the theoretical knowledge of design and psychology, and combines the author's visualization project design experience to divide the basic diagrams of data visualization into data distribution, temporal expression, domain comparison, spatial expression, local whole, and data relationship, and establishes the deep association with the sub-patterns of imagery diagrams through the deep analysis of the visual presentation and interaction factors of data visualization expression. At the same time, the seven categories of abstract sub-patterns that have been systematically researched and verified are illustrated figuratively, and on this basis, the design inspirations for a visual representation of data are proposed for basic, force, control, spatial, process, composite, and attribute schemas. Based on the background of the intersection of meaning construction theory and design disciplines, a model of cultural and creative product design matching the project promotion process is established, design activities in each stage, available design methods, and design points are clarified, and design guidelines based on meaning construction theory are proposed; finally, a cultural information model is constructed to verify the validity and feasibility of the theory.

Keywords: Computer-aided; perceptual imagery system; cultural and creative products; design evaluation
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1 INTRODUCTION

In the Internet era, people's consumption behaviors are quietly changing with convenient communication methods, developed connectivity, and huge information flow of the Internet. The way of production and life of enterprises and the economic market they depend on have also changed dramatically, and various Internet cultural enterprises have sprung up, deepening the impact on traditional cultural and creative industries. Therefore, to enhance the competitiveness of cultural and creative products in the market and promote the sustainable development of the cultural industry, new requirements have been put forward for the development of cultural and creative products [1]. To effectively detect consumers' needs and grasp the rapid development direction of the market, to maintain the strong market competitiveness of cultural and creative products has become one of the most important product design principles in contemporary times. Consumers' needs for products are becoming increasingly complex and diverse, and among the many needs, functional and perceptual needs are essential to improve consumer satisfaction [2]. The quality attributes of a product are given by using specific design techniques and through specific design processes. Due to the increasing maturity and convergence of product technologies, which leads to the lack of effective technical barriers between competitors, it has become difficult to develop a competitive advantage based on functional design in a fully competitive market, and the formation of product attractiveness is no longer simply about providing functionality, but about the effective expression of product perceptual attributes [3]. Therefore, the accurate, timely and effective expression of product perceptual attributes through design has become an indispensable way to improve the quality attributes of products and consumer satisfaction.

The traditional design approach of manual information processing relying only on the subjective experience of designers has been difficult to adapt to the rapidly iterating product appearance design process and ensure accurate and efficient information processing results, and many complicated and trivial manual operations tend to cause long design cycles, high costs, and low accuracy and efficiency. In modern product design, computerizing the design work of processing information of each design element is considered an effective way to improve design efficiency. The introduction of technologies such as computer-aided design and digitization into the design process can help to reduce the burden of designers, enhance the innovation, predictability, and success of design solutions, and thus improve the design quality and market competitiveness of products. It is an important trend in this research field to promote the development of product appearance imagery design toward digitalization and to achieve efficient design and development of product appearance under accurate prediction of perceptual appeals. By abstracting and describing the information of design elements such as product shape, color, and imagery information and data, so that computer systems can automatically recognize and process this information, the product appearance design optimization and decision-making process can be automated, and provide greater innovation space and opportunities for product appearance imagery design.

We propose a multi-domain heterogeneous data visualization design methodology based on imagery schema and construct a multi-domain heterogeneous data visualization design model under the perspective of imagery schema. It provides designers with innovative design perspectives, brings novel user interface design to design works, and creates a better user experience for users. This is studied in Chapter 3 and Chapter 4 of the article. Schema is a cross-cultural, cross-racial, cross-geographical, and cross-age abstract structure rooted in the deepest level of human mental models, extracted from the recurring cognitive experiences in human activities, and is important for people to establish structural cognition of the objective world relationships. The imagery schema has the nature of a schema, while the cognition of complex concepts is accomplished by projecting the abstract structure from the source domain to the target domain. In the construction of a multi-domain heterogeneous data visualization system, the generation mechanism and expression mechanism of visual graphs are constructed by algorithmic imagery schemas. The algorithm is strongly related to the imagery schema and the logic of multi-domain heterogeneous data analysis and expression, i.e., both have an abstract logic.

2 RELATED STUDIES

In terms of research on product optimization design methods, scholars such as Wang has elaborated on the concepts related to the application of perceptual imagery in the product design process, studied the aspects of perceptual imagery, design knowledge, and user knowledge from the perspective of perceptual engineering, understood the methods and techniques involved in the application of perceptual engineering to the design field, and discussed the development direction and research focus of perceptual imagery, with the main directions being emotion computation, artificial psychology, neuroscience and machine simulation to provide more development ideas and innovative directions for the methods of product optimization design [4]. Dilling et al. [5] demonstrated that the product design process of perceptual engineering includes the steps of clarifying the situation of the designed product, determining the perceptual vocabulary, identifying the design elements, evaluating the perceptual vocabulary based on product examples, converting the perceptual evaluation scale into an engineering scale, and validating the results. Camba et al. [6] investigated users' preference for product perceptual imagery, and their research process combined quantitative description of shape tracing points with a qualitative description of shape deconstruction to clarify product shape characteristics and used statistical methods to obtain the mapping relationship between product shape characteristics and users' perceptual imagery, to guide and optimize product shape design, through the example of bicycle frame shape design. The study exemplifies in detail the steps of perceptual engineering applied in the design field. Based on the three levels of culture theory and Kano theory, Loureiro et al. [7] extracted cultural symbolic features and cultural elements, analyzed, and constructed a cultural feature weighting model, and used the West Lake cultural umbrella as an example for design practice to verify the validity and feasibility of the theory.

Lisińska-Kuśnierz et al. [8] proposed a specialized system called hybrid sensual engineering system i.e., forward sensual engineering system and inverse sensual engineering system, which contains multiple affective responses, integrates the support vector regression approach, and converts the multi-objective genetic algorithm into a hybrid sensual engineering system scheme, while the forward-style system is mainly used to generate product alternatives and the inverse style system is used to predict the affective responses of new product designs to facilitate the development of product form designs. In the above, more domestic, and foreign experts and scholars have conducted detailed research on the concept, classification, design methods, steps, and application areas of perceptual design, which has paved the way for the development of the perceptual design. Zhou et al. [9] proposed the design and evaluation method of product modeling based on perceptual engineering, and analyzed an automobile dashboard as an example, based on a questionnaire survey, and quantified the user's perceptual imagination of the dashboard by semantic differential method, and built a correlation model between the design elements of dashboard modeling and the user's perceptual imagination, which is of guiding significance for designers to carry out product concept design activities. It is a guide for designers to carry out product conceptual design activities, and at the same time, the user's sensory characteristics are integrated into the product appearance design.

Experts have carried out extensive and in-depth research on the optimization of product form design, and conducted detailed studies on the shape, color, and material dimensions of product form, and established quantitative relationships between form and user imagery, i.e., mapping relationships and related models, which laid a good foundation for the subsequent research on product form design combined with user cognition. By carrying out multi-dimensional and multi-angle morphology research, it is necessary to make more combinations, innovations, and improvements to product morphology design methods, and to better combine psychological cognitive factors with design, to improve the matching degree between user cognition and product needs in perceptual design. Cognitive processes, approaches, and models are also applied to specific perceptual designs, all of which promote the establishment of evaluation, data support, and scientific basis in perceptual design, proving the effectiveness of eye-tracking technology and the field of cognitive science for the establishment of design-assisted systems that can build design-assisted evaluation systems for designers to carry out design activities and create new design ideas.

3 ANALYSIS OF COMPUTER-AIDED PERCEPTUAL IMAGERY SYSTEM FOR CULTURAL AND CREATIVE PRODUCT DESIGN

3.1 Analysis of Computer-Aided Perceptual Imagery System

Computer-aided design technology is mainly divided into 2D drawing technology represented by CAD and other graphic design software, 3D production technology represented by Maya, 3DSMAX, SKETCHUP, etc., 3D printing technology represented by solid printing and experience interaction, virtual reality technology, GIS, and other new technologies, the rise, and application of these auxiliary technologies help planners [10]. The rise and application of these assistive technologies help planners to better improve their work efficiency and express their design concepts. 2D drawing technology, 3D production technology, 3D printing, and virtual reality technology are not used independently in one part of the design but are more of an interplay between technologies. These new technologies include computers, art, and design, landscape architecture, etc. The integration of multidisciplinary knowledge greatly expands and extends the scope and connotation of residential planning and design.

Design is to solve this problem of the relationship between sensation and cognition. In visual design (interface, environment, product appearance, etc.) and abstract multi-domain heterogeneous data visualization design, converting information, extracting knowledge, conveying meaning, and achieving experience are the basic requirements, and the starting point for designers to explore the potential of information and explore innovative perspectives. The objective world and information society will continue to produce a huge amount of multi-domain heterogeneous data, and human's ability to perceive information existing employing numbers and text lags the understanding of graphic symbols. Data visualization design is an important way to transform abstract data into a visual view that can be easily perceived, accepted, and understood by users.

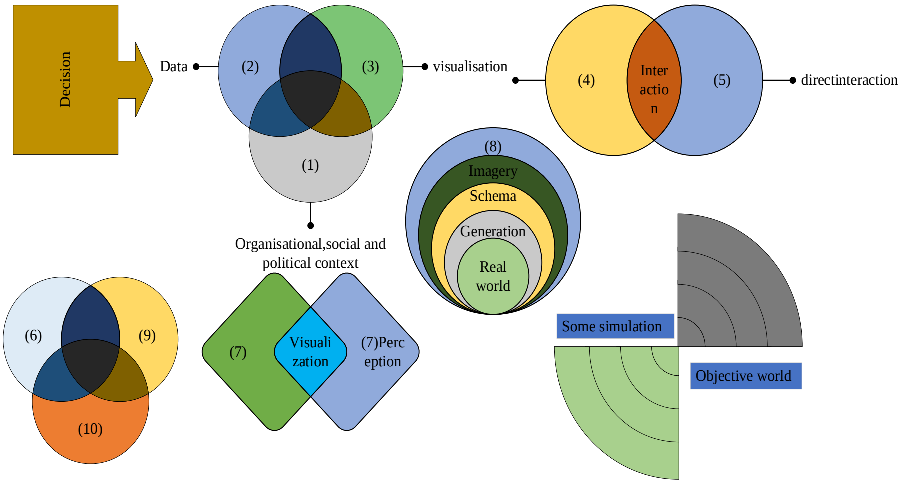

Figure 1: Flow chart of data visualization and analysis.

As can be seen in Figure 1, the starting point is the abstract data (1), which is processed (2) by algorithm design (machine learning, statistics, etc.) and then visualized (3) and received and understood by the user (4) for problem-solving, statistical analysis, etc. Sector (5) represents the interaction process between the user, data processing, and visualization. When multiple users are involved in this process, a group collaboration (6) is formed. However, the role of the user goes beyond the direct interaction with the visual analysis; the data for the visualization comes from the objective world (7) (or some simulation of the objective world) and the user uses this data to make decisions (8), which affects the user's behavior in the objective world (9) and ultimately the real world (10). In steps 1-5, the imagery schema affects the generation of the visualization graphics and the user's perception of the interaction.

Uncertainty still exists in the process of data visualization and analysis. The established visualization algorithms are inherently uncertain, and the models and parameters used for visual representation and visual analysis may cause variability in the visualization results and induce uncertainty. Different visualization results in turn cause uncertainty in the interpretation of visualization results by users. Deterministic data visualization results reflect the characteristics of the data itself, while the uncertainty in multi-domain heterogeneous data visualization is the important source of knowledge extraction and knowledge discovery, which can be enlarged, highlighted, highlighted, and enhanced in visual representation, thus reminding users to focus on and helping them analyze the details of it.

Imagery schema is a dynamic configuration that gives coherence and structure to human experience; it is a meaningful and organized pattern of experience, a conglomeration of human experience. This conglomeration of experiences can help people establish a structural perception of objective world relations, which enables them to sense and deal with related matters. Appearances mean that people can recognize and deal with things by their intuitive senses without causing accidents or errors. If a certain interaction, a software interface can be used to get a very intuitive appearance, usually means that it is the same as the user is already familiar with the way of operation. Specifically, emergent use is defined as "the extent to which a product can be used subconsciously with prior knowledge to produce effective and satisfying interactions with minimal cognitive resources.

As a method to explore the correlation of variables, the principal component analysis represents the original multivariate data through a small number of linearly uncorrelated principal component data based on linear transformation. Principal component data reveals the intrinsic connection between the original data and eliminates its correlation, thus reducing the data dimensionality and simplifying the analysis and processing process for high-dimensional data. The product 3D modeling quantification data is obtained by using the product 3D modeling quantification mathematical model. The model uses a 3D mesh model, spherical harmonics, and self-encoder technology to complete the data extraction of the triangular mesh model, spherical harmonic coefficients conversion and data dimensionality reduction, etc. After the data processing process, the comprehensive quantified information of product 3D modeling is characterized by the principal component data of spherical harmonic coefficients. The product color quantization data is obtained by the product color quantization mathematical model. After selecting the color quantification model under the appropriate surface color system, the product color is quantitatively described by the combination of color variables of the main colors corresponding to the main color-assigning areas of the 3D modeling surface, as shown in Figure 2.

This paper proposes a positioning method that incorporates the mathematical model of color quantification into the color imagery positioning process and uses the color quantification data obtained from this model to participate in the construction of a comprehensive evaluation model of color imagery and to complete color imagery positioning in this way. The specific process of this method includes: determining the color sample set and color imagery word set, mathematical description of color quantification, color imagery measurement, color imagery comprehensive evaluation model construction, and color imagery positioning.

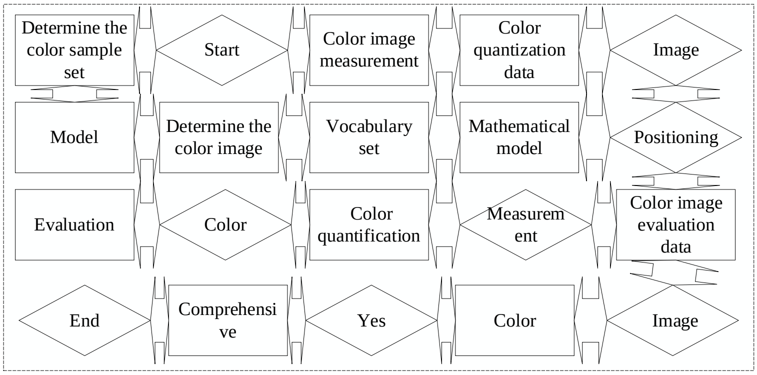

Figure 2: Product color imagery positioning process.

3.2 Evaluation Analysis of Cultural and Creative Products

Human perception of products exists in the form of symbols of images, representations, and concepts; therefore, the meaning of products is presented in the form of symbols. From the perspective of design, the ultimate goodness of meaning construction is reflected by the designed product. Determining the meaning of the product to be conveyed is the key to symbolize the meaning of the product. From the previous study, it is known that the level of product meaning includes three levels: sensory impression, user experience, and cultural connotation. The product elements mainly refer to the design language, through which the user realizes the process of perceiving, understanding, and experiencing the product, thus completing the construction of the objective context. This paper summarizes the formal elements of product design according to the classification characteristics of cultural and creative products, and combined them with the previously summarized contexts, as shown in Figure 3.

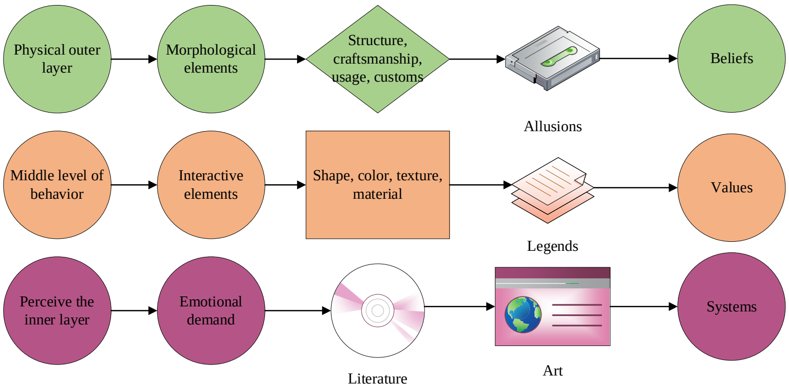

Figure 3: Design elements of cultural creative products

The product is the carrier of cultural content information, and its product attributes and creative design, as part of the symbols, reflect the cultural connotation. Aesthetic information refers to the impact of design language on the user and the emotional experience; functional information refers to the actual performance of the product, and experience information refers to the category and social value of the product that will be brought to the user. On the premise of the same cultural content information, different product design information will make the product design affect change dramatically, thus affecting the process of meaning construction.

The process of receiving information refers to the whole process of users' exposure to cultural information, which is the most direct and instinctive perspective to cognize the product. The user's sensory organs receive information and form sensory impressions of the product, while the interaction with the product leads to emotional experiences. Therefore, the five senses of human contact and the ergonomics of the product are the influencing factors of the dimension of receiving information. The five senses of contact include vision, hearing, smell, touch, and taste, and nowadays, value control refers to the visual effect of products that affects people's information receiving effect.

Many factors are affecting the positioning and matching of information by users, and since people are individuals living in the society, their thoughts are interfered with by the society and environment they live in, so they are mainly divided into three factors, namely, personal thoughts, surrounding environment and social conditions. Personal thought refers to the user's own life experience, knowledge system, life experience, cultural cognition, aesthetics, values, etc., and thus influences the matching process of information positioning; surrounding environment refers to the influence of surrounding factors, including the concept of people around, the inculcation of the living environment, etc.; social conditions refer to the influence of the social environment, mainly referring to social culture, mainstream fashion, etc. Cultural products need to be recognized in mainstream society, and the understanding and tolerance of cultural connotation in the society will invariably interfere with people's judgment, which will affect users' matching and positioning of information.

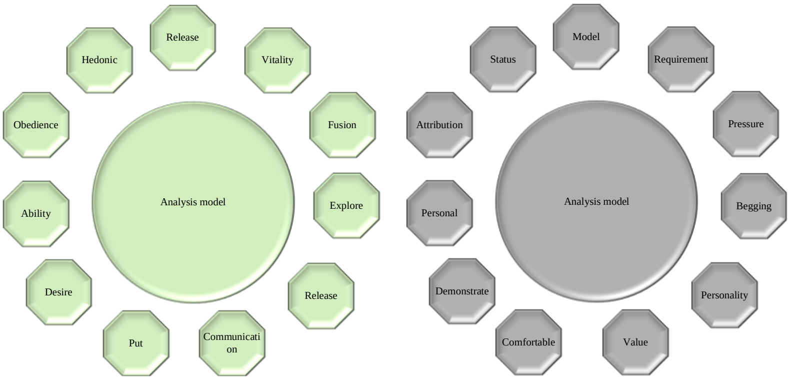

Figure 4: User emotional needs analysis model.

It is important to note that the imagery schema only describes the abstract structure, and the concrete instantiation of the imagery schema needs to be determined by the designer according to the specific circumstances of use. This leaves room for designers to show their design creativity. For example, in a thematic river emotion visualization graphic, the large and small size of the graphic map the more and less of the corresponding theme, respectively. The specific presentation, color, etc. may vary, but the relationship between the size at the core and the amount of theme mapped is fixed. Figure 4 shows the visualization graphics of theme rivers with different design styles, and although the color and appearance of the visualization graphics designed by different researchers vary, the span of the color block corresponds to the magnitude of the topic is constant.

4 ANALYSIS OF RESULTS

4.1 System Performance Analysis

Figure 5 shows the three fitting errors of the sample car at different maximum harmonic frequencies N. The figure visually reflects the trend of the errors: with the increase of the maximum harmonic frequency, the three errors of the elliptic Fourier technique converge rapidly and reach the minimum error range required to meet the accuracy of the study at the maximum harmonic frequency N=30, when the maximum error is less than 1.4 mm, the mean error The maximum error is less than 1.4 mm, the mean error is less than 0.7 mm, the standard deviation of error is less than 0.3 mm, and the error remains relatively stable. Therefore, the maximum harmonic frequency N=30 is determined.

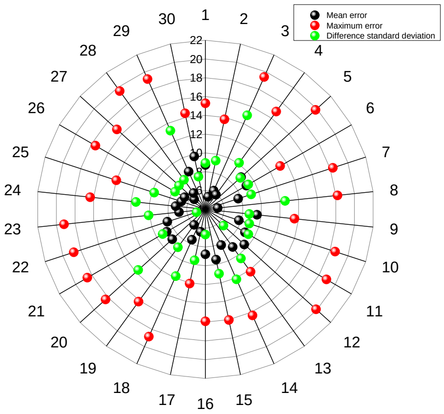

Figure 5: Mean error of the elliptical Fourier technique for the overall sample of 20 benchmark cars.

The elliptic Fourier coefficient matrix of the overall sample was obtained using N=30, and then the matrix was dimensioned down by principal component analysis to obtain the principal component data matrix of the overall sample, as shown in Figure 6.

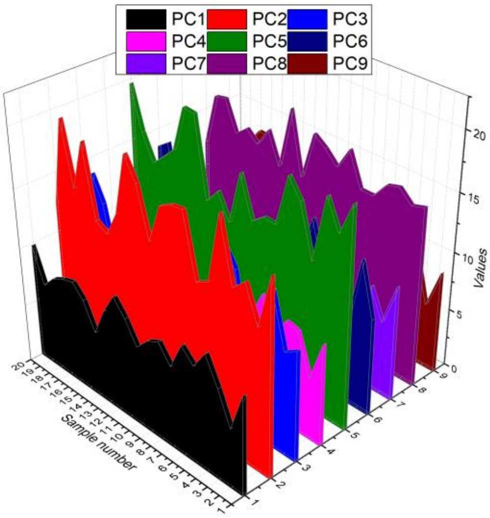

Figure 6: Principal component data matrix of the overall sample.

Further, the sample 3D modeling is pre-processed by the computer-aided 3D design software to obtain the initial sample mesh data containing vertices and faces. The number of vertices and faces of each sample is set to nearly 20,000 vertices and 40,000 faces to standardize the 3D modeling mesh data of different samples. Then, the mesh data of all samples are extracted using PHARM software. After the spherical parameterization, the spherical Fourier transform is applied to the spherical vertex coordinates of each sample to obtain its spherical harmonic coefficients. In this process, the visual effect of 3D modeling reconstruction for each sample at different harmonic frequencies is tested, and the ideal harmonic frequency l is determined to be 30. The 3D modeling reconstruction effect of this sample at different harmonic frequencies is given. With the increase of the harmonic frequency, the surface features obtained by reconstruction become increasingly abundant and fine. When l=30, the visual effect of the reconstructed model is sufficient to reflect the main 3D modeling features of the original model, and the shape noise can be well controlled. Therefore, the spherical harmonic coefficients of the overall sample are calculated with this harmonic frequency.

4.2 Product Design Evaluation Analysis

Through the data analysis of SPSS software, Figure 7 shows the overall chi-square test results and the overall one-way ANOVA results, respectively. The one-way ANOVA synthesis table of the screened oculomotor indexes shows that the significance levels of maximum gaze time and maximum sweep time are less than 0.05, indicating that the indexes differ significantly in different electric kettle morphological designs and can be used for the subsequent relationship model. Therefore, the maximum gaze time and maximum sweep time were selected as the two eye-movement indicators for the follow-up study.

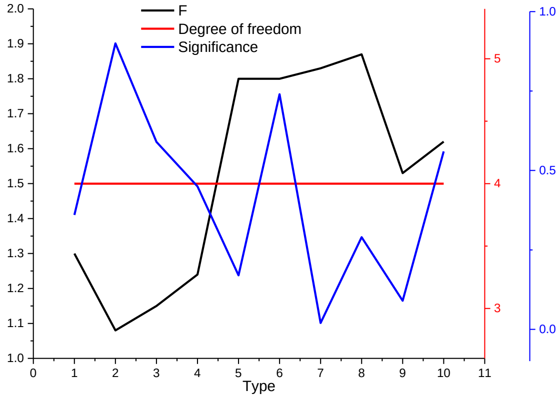

Figure 7: One-way analysis of variance for indicators.

Based on coding, the relationship models between different eye-movement indicators and morphological design elements are established separately by using partial least squares regression method, and analyzed to clarify the weight ranking of design elements, and find the important design elements affecting users' visual cognition according to the ranking, to further select the optimized design scheme and provide design guidance direction for its morphological optimization design. According to the analysis of the product form visual cognition model, during the eye-movement experiment, the target area or area of interest of the experimental sample will attract the selective attention of the subject (the eye-movement data is extracted from the area of interest, i.e., AOI). However, changes in the level of the morphological design elements will affect the changes in the values of the eye movement indicators, so a model of the relationship between them is needed. In this study, the design morphological parameters corresponding to each target sample were used as independent variables, and the maximum gaze time and maximum sweep time were used as dependent variables, respectively.

The paired-sample t-test for the maximum gaze time was 0.065, which is greater than 0.05. This indicates that there is no significant difference between the measured and predicted values, and the test results indicate that the model is valid. This demonstrates that objective data based on user perceptions can be reflected as real subjective data with high stability and accuracy, and then the model can quickly and efficiently predict users' perceptions of the product form and finally improve the match between product design goals and user needs.

5 CONCLUSION

The sub-patterns of imagery can bring design inspiration to data visual expression, specifically: the basic pattern can play the role of expression, substitution, and comparison to data visual expression; the force pattern can play the role of compliance, compensation, and enhancement to data visual expression; the control pattern can inspire data visual expression in terms of function, frequency of use and user behavior; the spatial pattern can play the role of guidance, focus and feedback to data visual expression; the process pattern can help data visual expression in the cycle and iteration of the whole product creation process and effective presentation; the composite pattern can bring simplification and simplification to data visualization design. The spatial schema can guide, focus and give feedback to the data visual expression; the process schema can help the data visual expression in the cycle and iteration of the whole product creation process and the presentation of the effect; the composite schema can inspire the data visual design by simplifying the complexity, corresponding to the beam and correlating with multiple domains; the attribute schema can inspire the data visual expression by corresponding to the same number, coexisting with multiple domains and sparse and dense design. Imagery is psychologically and physiologically realistic, and its spatial schema is important for the interaction construction of multi-domain heterogeneous data visualization, which can play a good role in promoting the interaction mode, interaction principle, and interaction dimension.

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