Research on Visual Perception Feature Extraction of Textile Color Matching and Clothing Display Optimization Strategies

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ABSTRACT Color is the most direct visual attribute of apparel products and plays an important role in attracting consumer attention, conveying brand concepts, and stimulating purchasing interest in terminal displays. This study develops an optimal color-matching method for apparel display by combining quantitative color analysis with visual perception experiments. Common apparel display images are first collected, and the main hue, contrast, and spatial distribution characteristics of color samples are extracted in HSV color space to form a quantitative description system for color matching. Because apparel color perception depends on visible-spectrum optical interaction and image feature extraction, the method provides an engineering-oriented basis for evaluating visual display effects. A visual perception experiment is then designed in which participants judge the visual saliency, harmony, and preference of different color matching patterns. Correlation analysis is used to explore the internal relationship between quantitative color characteristics and consumer visual perception, and targeted color optimization strategies for apparel displays are proposed. The results show that hue-difference ratio and brightness-difference ratio are positively correlated with visual saliency, while color matching with similar saturation is more likely to obtain higher harmony scores. Adjacent color matching based on the main hue receives higher preference scores, whereas high-purity complementary matching attracts attention rapidly but shows lower harmony.

INDEX TERMS textile color matching, visible-spectrum imaging, visual perception, feature extraction, display optimization

I. INTRODUCTION

IN the experience economy era, the apparel retail outlets have been transformed from basic markets to central spaces for control of brand images and shaping consumer experiences. Among the numerous factors that affect the consumers initial impressions and buying decisions, color possessing its own powerful visual impact yet also being endowed with emotional appeal has become a key factor in the design of displays. A successful color scheme not only instantly catches the eye of passersby but also guides the customer's browsing path through the store, establishing a cohesive shopping atmosphere that enhances product engagement and conversion rates. However, the existing apparel display practices still largely depend on the experience and intuition of display designers without a profound knowledge and quantitative analysis of the inherent laws governing the relationship between color and consumer visual perception. Questions like what the harmonious combination of colors should be or what combinations are the most observing, and how different color groups will affect the aesthetic preferences of consumers have not yet been systematically and scientifically answered.

With the accelerated development of computer vision technology and color science, the issue of quantitative description and analysis of color has become possible. Existing research is either centered on the exact control of individual clothes color, stylistic clothes suggestions according to skin tone or individual characteristics, or psychological effects of color in certain situations. For example, the scholars have made in-depth discussions about color formulations, color difference control, and accuracy of color memory in textiles, while some studies have been conducted for the role of clothing color in individual impression evaluation. However, these research perspectives have not yet been extended to the color combination relations between multiple garments in real-world display scenarios, and there is a lack of a systematic manner for relating objective quantitative color characteristics with subjective visual perception of consumers. Clothing display is a complex visual field which involves the interacting of multiple color elements, simply analyzing the color attributes of single garments is not enough to explain the aesthetic principles and visual efficiency of such a whole display effect.

In light of this, this paper proposes a research method for extracting visual perception features of textile color matching and optimizing clothing display strategies. The research aims to construct a complete closed loop from quantifying objective features to verifying subjective perception: First, key color feature parameters are extracted from clothing display images using image processing technology; second, consumer visual perception data on display colors are obtained through psychological experimental paradigms; finally, statistical methods are used to reveal the correlation mechanism between the two, and based on this, practical optimization strategies for display color matching are derived. This research not only expands the perspective of clothing color theory research but also aims to provide a quantifiable and replicable scientific decision-making tool for clothing brand terminal visual marketing, helping companies enhance brand competitiveness through visual strategies in a fierce market competition.

II. RELATED WORK

In the field of clothing and textile science research, color has always been a core element that runs through product development, quality control, consumer perception and marketing. The two-stage framework proposed by Zhang et al. [1] can effectively handle clothing of different styles and materials, and provides a low-cost and high-efficiency visual content generation solution for clothing e-commerce. The color formula of textiles is the key to determining the accuracy and consistency of the final product color. Chaouch et al. [2] sorted out the research methods of color formula in the textile field. Chae [3] emphasized that when formulating textile color standards, observation conditions must be taken into consideration, and proposed the idea of modifying the color difference formula based on specific observation conditions in order to achieve more accurate color quality control. Dong et al. [4] selected color samples with different hues, brightness and saturation, applied them to various clothing styles, and invited the subjects to score from multiple dimensions such as environmental protection, naturalness, durability and ethics. Ichinose et al. [5] explored the effectiveness of clothing color as a personal climate adaptation strategy by combining field measurement and numerical simulation.

Lee et al. [6] assessed the accuracy of color memory by comparing the color difference between the subjects' choices and the original colors. Su et al. [7] analyzed user facial photos using image processing technology, extracted biometric information such as skin color and hair color, and the recommendation algorithm combined the user's seasonal characteristics with other preference characteristics to perform multi-dimensional matching, and finally generated a personalized clothing recommendation list. Zhou et al. [8] proposed and developed an automatic color sorting system based on computer vision. Wen et al. [9] examined the evaluation of male and female target faces wearing red, blue or white clothing on three dimensions: attractiveness, warmth and ability by 539 participants. Park et al. [10] developed a clothing recommendation system based on user body size and skin color. The system recommends suitable sizes based on the body size data input by the user, and identifies the user's skin color through image analysis technology. The above studies did not explore the color matching relationship of multiple garments in the display scene and its influence mechanism on consumers' visual attention and aesthetic preferences, and lacked a strategy framework for systematically optimizing the color matching of clothing display from the perspective of visual perception feature extraction. This paper aims to construct a research method that integrates color quantitative analysis and visual perception experiments, and to explore the visual salience, harmony and preference of different color matching patterns in display contexts, so as to provide a scientific theoretical basis and practical guidance for the display design and color marketing of apparel terminals.

III. METHODS

A. EXPERIMENTAL SAMPLES AND IMAGE ACQUISITION

To ensure the representativeness and validity of the research sample, this study selected seasonal clothing products from five mainstream fashion brands as the source of experimental materials. The sample selection covered menswear, womenswear, and unisex styles, including basic categories such as T-shirts, shirts, dresses, and outerwear. In terms of color selection, based on the Munsell color system, it covered five main colors: red, yellow, blue, green, and purple, and further subdivided each main color into three levels of saturation (high, medium, and low) and three dimensions of brightness (high, medium, and low). Different three-piece clothing display units were constructed by combining items with different color attributes. Image acquisition was conducted in a laboratory simulating a standard clothing retail store environment. Professional photographic lighting equipment was used to ensure uniform illumination, with the color temperature set to 4000K–4500K to simulate standard retail LED lighting environments, which is more representative of the actual visual conditions in apparel terminal displays. All clothing samples were suspended on standardized display racks against a neutral gray background (N5 in the Munsell system) to minimize background bias while allowing for the observation of simultaneous contrast effects. This setup ensures that the visual interaction between the garments and their immediate environment more closely approximates real-world display scenarios compared to a pure white background. The original images were stored in RAW format, then uniformly converted to 24-bit bitmap format and color corrected to ensure that the image colors accurately reproduce the real objects [11-12].

B. QUANTITATIVE EXTRACTION OF COLOR VISUAL PERCEPTION FEATURES

In the color quantification analysis stage, this study extracted features from 24 collected display images based on the HSV color space. The HSV color space was chosen because its hue, saturation, and brightness components are independent, which better aligns with human visual perception of color. First, each image underwent preprocessing, including Gaussian filtering for noise reduction and image segmentation, to accurately extract clothing areas and eliminate background interference. Then, for each garment, the HSV value of its primary color was extracted, and three core quantification indicators for the entire display were calculated. The first indicator is the number of primary colors, i.e., the number of significant colors with a visual share exceeding 15% in a display. The second indicator is the hue difference value, obtained by calculating the angular difference between the primary colors of each pair of garments on the color wheel and averaging it, used to quantify the contrast intensity of the color combination. The third indicator is the average saturation and average brightness, along with the corresponding saturation range and brightness range, used to describe the overall vividness and tonal gradation of the color combination. Finally, the concept of color space distribution entropy was introduced, and the visual rhythm of the display colors was quantified by calculating the spatial distribution uniformity of different color regions on the image plane. All image processing and feature extraction work was implemented by calling the OpenCV library in the Python environment to ensure the standardization and repeatability of the extraction process [13].

C. VISUAL PERCEPTION EXPERIMENT DESIGN

To obtain real visual perception data on consumers' perception of different color combinations in clothing displays, this study recruited 60 undergraduate and graduate students with normal or corrected vision as participants, half male and half female, aged 19 to 28. All participants passed color blindness and color weakness tests and possessed normal color discrimination abilities. The experiment was conducted in a user experience laboratory with constant lighting. The stimuli were the aforementioned 24 sets of clothing display images, presented on a calibrated professional monitor. The experiment included three core evaluation tasks. The first task was visual saliency evaluation, which combined eye tracking and subjective rating. Participants freely viewed each image for 5 seconds, and an eye tracker recorded their initial fixation time and total fixation duration. Subsequently, participants rated the "visual impact" of the image on a 5-point scale. The second task was color harmony evaluation. The image presentation time was unlimited, and participants rated the "color harmony" of each display on a 5-point scale based on their personal aesthetic sense. The third task was preference evaluation, requiring participants to rate their 'visual appeal preference' or 'initial attraction' for each displayed product combination on a 5-point scale, focusing on the immediate aesthetic impact of the color matching rather than a final purchase decision. A neutral gray screen was displayed before each image as a visual buffer to avoid interference from the color afterimage of the previous image. All evaluation data were entered into the database in real time for subsequent statistical analysis. Through this experimental design, the study obtained a multi-dimensional visual perception dataset encompassing objective eye-tracking indicators and subjective psychological perception. This study was approved by the Ethics Committee of Zhejiang Fashion Institute of Technology, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

IV. RESULTS AND DISCUSSION

A. RESULTS OF COLOR QUANTIFICATION FEATURE ANALYSIS

Color feature extraction has been applied on 24 sets of clothing display images to get systematic quantitative data. Statistical results show that number of dominant colors in the combinations of sample demonstrations ranged from 2 to 4 with the combinations of 3 dominant colors being most common and accounting for 62.5%. The range of hue difference values was very broad with a minimum difference of 22.5deg (adjacent color schemes) and maximum of 148.3deg (complementary color schemes), leaving a wide range of contrast types from soft to strong contrast. Regarding mean saturation the values were within a range of 0.25 to 0.82 (saturation values range from 0 to 1) and average brightness was within a range of 0.35 to 0.88. In order to further depict the specific distribution of all the quantitative features, the color feature parameters of some representative samples are summarized in Table 1.

As shown in Table 1, different samples in display show large differences in various quantitative color indicators. Sample S05, with high hue difference of 142.7deg and relatively high average saturation of 0.76, shows a strong color contrast effect, and sample S01 can be seen as a soft color scheme of analogous color schemes, with a low hue difference value of 35.2deg. Regarding the distribution of color space, based on the color space distribution entropy of sample S18, 3.12, the distribution of the color space is more dispersed and the rhythm is stronger, and the distribution of the color space is more concentrated in sample S05, and the color space distribution entropy is low. These quantitative characteristics form an objective basis for further correlation analysis with visual perception data. Statistical analysis of all samples shows that the difference between saturation and brightness in the end of the season promotional areas will be relatively large, aiming to attract customers through good eye-catching effect, and the difference between the color tone of the ordinary-priced areas will be controlled within 60 degrees, aiming to achieve a more harmonious eye-catching effect.

TABLE 1. Color Quantification Feature Parameters of Representative Clothing Display Samples

Sample number	Number of main colors	Hue difference value (°)	Average saturation	Extremely poor saturation	Average brightness	Extremely poor brightness	Color space distribution entropy
S01	3	35.2	0.58	0.21	0.72	0.18	2.35
S05	2	142.7	0.76	0.08	0.65	0.25	1.87
S12	3	88.5	0.43	0.35	0.48	0.42	2.76
S18	4	67.3	0.51	0.42	0.55	0.38	3.12
S22	3	125.6	0.69	0.15	0.61	0.29	2.54

B. STATISTICAL ANALYSIS OF VISUAL PERCEPTION EXPERIMENT RESULTS

The visual perception experiment gathered information from 60 subjects for the saliency, coordination, and preference of 24 sets of display images, along with the recorded objective indicators of eye-tracking. After the cleaning and removing outliers of the raw data, 1428 valid samples were collected. For the quantitative research, overall statistical results showed the mean value of subjective score of visual saliency was 3.42 (standard deviation 0.87), the mean value of score for coordination was 3.58 (standard deviation 0.92), and the mean value of score for preference was 3.37 (standard deviation 1.01). Eye-tracking data showed 71.3% of the participants first fixation point was in the highest color saturation area of the image and thus verifying the preferential capture effect of highly saturated colors onto visual attention. To further improve the analysis, all samples were classified into four types according to color matching patterns: adjacent color matching, analogous color matching, contrasting color matching and complementary color matching. The classification statistics is shown in Table 2.

TABLE 2. Visual perception score statistics under different color matching modes

Matching mode	Sample size	Visual saliency equal score	Coordination is evenly distributed	Preferences are evenly distributed	Average total fixation time (seconds)
Adjacent color scheme	6	2.89	4.21	3.98	3.85
Analogous color scheme	7	3.24	3.95	3.62	3.72
Contrasting color scheme	6	3.78	3.18	3.11	4.13
complementary color matching	5	4.15	2.63	2.58	4.36

Table 2 shows a clear trend that with increasing intensity of color contrast the visual salience score increases. Complementary color combinations obtained the highest salience with 4.15, also average total gaze duration was the longest at 4.36 seconds in the paper, indicating that good color contrast can actually effectively extend the time consumers spend looking at the product. However, the harmony and preference scores have the opposite pattern. Analogous color combinations had the highest harmony score of 4.21 and preference score of 3.98 whereas complementary color combinations had the lowest score in both indicators. This result exposes a potential disconnect between the capturing power of visuals and a visual aesthetic: color combinations that can catch attention quickly may not necessarily earn the visual aesthetic and purchase preference of consumers. Notably got relative balance between visual salience (3.78) and harmony values (3.18) and preference score was also in moderate level suggesting that they may have good compromise effect between getting attention and maintaining likability.

Table 3 further analyzes the impact of color brightness and saturation combination characteristics on perceptual evaluation. The samples were grouped according to their average brightness and average saturation, with the median of all samples serving as the boundary between high and low groups.

TABLE 3. The Influence of Brightness and Saturation Combination Characteristics on Perceptual Evaluation

Brightness level	Saturation level	Sample size	Visual saliency equal score	Coordination is evenly distributed	Preferences are evenly distributed
high brightness	High saturation	5	4.02	3.12	3.28
high brightness	low saturation	6	2.95	3.87	3.54
Low brightness	High saturation	7	3.81	3.08	3.05
Low brightness	low saturation	6	2.78	3.45	3.17

Table 3 shows that the high-brightness, high-saturation combination has the most prominent visual salience (4.02 points), but its harmony score is low (3.12 points), reflecting that the visual impact of strong, vibrant colors often comes at the cost of harmony. In contrast, the high-brightness, low-saturation combination, although having a lower visual salience (2.95 points), achieved the highest harmony score (3.87 points) and a relatively high preference score (3.54 points), presenting a soft and refreshing visual experience that aligns better with general aesthetic preferences. The low-brightness, low-saturation combination has the lowest visual salience among all categories (2.78 points) and also has an unsatisfactory preference score, suggesting that large areas of dark, muted color combinations should be used cautiously in display design to avoid creating a visually dull effect.

C. CORRELATION ANALYSIS AND OPTIMIZATION STRATEGIES BETWEEN COLOR FEATURES AND VISUAL PERCEPTION

Pearson correlation analysis was conducted upon the color quantification features extracted in Section 3.2 as well as the data from the visual perception experiment in Section 4.2 and several significant associations were found. The results of the analysis conducted indicate that differences in hues values are significantly and positively correlated with visual salience scores, but are significantly and negatively correlated with harmony scores. This means the greater the contrast of hues in a display arrangement, the easier it is to attract the attention of the consumer, but it will also have the tendency to diminish the harmony of the whole arrangement. Saturation difference also correlates positively with visual salience, when high saturation and low saturation objects are present at the same time in a display, the resulting high contrast performs an effective stimulation of visual attention. It is worth noting that the color space distribution entropy and preference scores have inverted U-shaped curve relationship; a moderate degree of distribution entropy will make the preference score the highest, as long as the color distribution is not too concentrated or scattered area, there will be no good experience for the audience aesthetic feeling.

Based on the results obtained above, this study suggests the following strategies to optimize the matching of colors in clothing displays. First, dynamically adjust the intensity of color contrast according to the display purpose. For window displays or promotional areas, while high hue differences (100°–150°) and high saturation differences effectively capture initial visual attention, they should be used with caution due to their lower preference and harmony scores. Such strategies are best suited for short-term 'stop-and-look' triggers rather than long-term brand affinity building, and should ideally be balanced with neutral elements to mitigate aesthetic fatigue. However, for use in such displays the area which is used to complete the colour combinations should be controlled or achromatic colours used for visual buffering to alleviate the discomfort caused by strong colour clashes. Second, for the full-price display areas in the store, as a basis, adjacent or similar colors are suggested to ensure the score of high harmony and the formation of a comfortable shopping atmosphere. In this area, visual layering can be enriched by maintaining a brightness difference (controlled between 0.3–0.4) to prevent visual monotony, while ensuring a moderate average saturation of 0.4–0.6 to optimize aesthetic preference ratings. Third, rationally use the combination of color bright and color saturation. High brightness and low saturation combinations are for fresh and upscale visuals, which can be used for accessible luxury brands or spring/summer women's wear areas. For areas which require a more composed and professional image low brightness and medium saturation combinations may be used, however low brightness and low saturation combinations on large areas will be avoided in order to avoid a dated image. Fourth, optimize the spatial distribution of the colors. When designing displays, give careful thought to placing various colors of the visual plane, to ensure you avoid situating all the vibrant colors in a single corner of the display or distributing them evenly across the area. Create a moderate color spatial distribution entropy to be a hierarchical distribution of primary, secondary and accent colors creating a rhythmical yet uncluttered visual experience. Finally, ensure a dynamic display optimization mechanism based on feedback data. Physical retail terminals can implement these data-driven strategies by utilizing periodic visual audits. By using mobile image recognition tools to quantify the color features of current displays and correlating them with weekly sales or dwell-time data, managers can systematically update display layouts during scheduled seasonal or promotional rotations to achieve an evidence-based optimization loop.

V. CONCLUSION

This study focuses on the core issue of extracting visual perception features of textile color matching and optimizing clothing display strategies. It constructs a research methodology integrating quantitative color analysis and visual perception experiments. By extracting HSV color space features from 24 clothing display samples, a quantitative index system including hue difference value, average saturation and brightness, and color space distribution entropy was obtained. Simultaneously, a visual perception experiment incorporating eye tracking and subjective rating was designed to obtain consumer evaluation data on the saliency, harmony, and preference of the displayed colors. The preliminary results of this study suggest an observed correlation between quantitative color features and visual perception: hue difference and saturation range appear to drive visual attention, though excessive contrast impairs harmony perception within the tested sample set. While these findings provide a foundation for further research, the small sample size per matching category necessitates future validation with a larger, more diverse dataset to confirm these mechanisms as universal laws; moderate color space distribution entropy is beneficial for enhancing aesthetic preference; and high brightness and low saturation combinations perform best in preference evaluation. Based on these findings, display color optimization strategies are proposed, including dynamically adjusting contrast intensity, optimizing brightness and saturation combinations, and rationally planning color space distribution, providing a scientific basis and practical guidance for visual marketing in clothing retail terminals. This study has certain limitations: the sample categories mainly focus on everyday clothing and do not cover special functional and luxury categories; the experimental environment is a laboratory simulation, which differs from real shopping scenarios. Future research could incorporate virtual reality technology to create a more realistic shopping environment, expand the cultural background dimension of the samples, explore cross-cultural differences in color perception, and further improve the theoretical system and practical application of color optimization for clothing displays.

AUTHOR CONTRIBUTIONS

Conceptualization – Haiou Hu and Zhibao Cao; methodology – Haiou Hu and Zhibao Cao; investigation – Haiou Hu and Zhibao Cao; writing-original draft preparation – Haiou Hu and Zhibao Cao. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Ethics Committee of Zhejiang Fashion Institute of Technology, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

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