NCS-Based Extraction and Innovative Application of Lingnan Traditional Color Palettes in Packaging Design

Tao Feng[1,2]*

[1]Graduate University of Mongolia, Ulaanbaatar 14200, Mongolia, China

[2]Guangzhou Engineering and Technology Vocational College, Guangzhou 511325, Guangdong, China

*Author to whom correspondence should be addressed.

Abstract: This study examines the traditional Lingnan color spectrum, establishing a quantitative analysis framework using the natural color system (NCS). Field surveys and equipment measurements extracted typical colors from architecture, embroidery, and ceramics, combining colorimeter data with multispectral photography to create a dynamic database integrating chromatic values, material properties, and cultural semantics. Findings show Lingnan colors are shaped by both nature and culture, with monsoon-driven vegetation and Danxia mineral hues forming base colors, while clan rituals and folk beliefs reinforce cultural identity (e.g., "bright red signifies fortune"). Applying "parametric continuity–scene regeneration," desaturating colors by 20–30% and increasing brightness by 10–15 points improved youth acceptance (81%) and boosted sales conversion (herbal tea packaging +37%). The NCS framework enables cultural heritage integration into modern design, with future research exploring AI and smart materials for interactive applications.
Keywords: Lingnan traditional colors; Natural color system; Packaging design; Cultural heritage preservation; Innovative application

1. Introduction

1.1. Research background

Lingnan culture, spanning Guangdong, Guangxi, Hainan, and parts of Yunnan and Guizhou, blends Chaoshan, Hakka, and Vietnamese influences. It shapes folk beliefs, Cantonese opera, and architecture with flying eaves and blue brick carvings. Red and gold symbolize festivity and prosperity. Color impacts perception, emotion, and brand identity, with warm tones evoking warmth and cool tones conveying professionalism. Effective color use enhances design impact, market competitiveness, and innovation in visual communication.

1.2. Overview of the natural color system

The natural color system (NCS) standardizes color perception using hue, blackness, whiteness, and chroma, ensuring precision in design (e.g., NCS S 1080-Y10R). It enhances color consistency in architecture, branding, and heritage preservation. Unlike traditional palettes reliant on vague natural references, NCS provides exact coding (e.g., Lingnan's "Oyster Shell White" as NCS S 0502-Y10R), enabling accurate replication and modern applications while retaining cultural significance.

1.3. Research objectives and significance

This study utilizes the NCS system to quantify and reconstruct Lingnan's traditional color palettes, ensuring scientific preservation and dynamic inheritance. By transforming architectural, embroidery, and ceramic colors into parametric data, it establishes a systematic database for digital archiving and cross-media dissemination. NCS analysis of Cantonese gray sculpture documents hue deviations and contrast patterns, preventing color distortion from craft discontinuity and standardizing cultural heritage representation.

2. Literature review

2.1. Current research status in related fields

The study of color theory integrates physical properties, perceptual mechanisms, and cultural symbolism. In the Western context, this extends from Newton's experiments with light spectra to Ostwald's color solid and the Munsell system, which encompasses hue, value, and chroma [1]. The NCS system constructs a model of visual physiology based on the theory of color antagonism [2], supporting architectural and design practices. In the Eastern context, theories focus on cultural semantics. For instance, Wang [3] analyzed the connection between the "five-color system" and the philosophy of the five elements, while Li [4] revealed the logic of symbolic coding in regional colors. The Pan [5] promoted the modernization of traditional colors through the spectral digitization of Dunhuang murals. Current research merges standardization with cultural characteristics (such as the East Asian adaptation of NCS) and explores differences in visual cognition between tradition and modernity [6], although systematic innovation and transformation remain to be achieved.

As visual carriers of history and culture, traditional colors merge artistic expression, social values, and cognitive impacts within their theoretical and practical frameworks. Chinese traditional colors serve not only as decorative elements but also as cultural symbols that embody "ritual systems" and the philosophy of the five elements. In classical art, embroidery and painting enhance visual narratives through the contrast and harmony of specific colors, such as "vermilion" and "stone green." Additionally, Lai [7] explored how colors serve as signifiers in ancient Chinese ritual art, further establishing paradigmatic structures in cultural symbolism. Contemporary design reconstructs traditional color palettes to facilitate cultural translation. For example, a series of home products developed based on the colors of Dunhuang murals validates the competitiveness of traditional symbols in the modern market.

Innovations in research methodologies have advanced the quantitative analysis of traditional colors. Scholars utilized the NCS system to establish chromatic value calibration for the painted architecture of Jiangnan, creating a replicable design parameter library. This scientific approach preserves the cultural semantics of color while supporting its applicability in digital media and industrial design, highlighting the organic dialogue between tradition

and innovation. Similarly, Fraser and Banks [8] discussed the need for designers to balance traditional color associations with modern applications, highlighting how different cultures attribute varying symbolic meanings to color.

2.2. Theoretical foundation of design innovation

Design innovation drives product differentiation and social progress by integrating technology, aesthetics, and user insights. Buchanan [9] asserted that the essence of design lies in the "reconstruction of meaning in man-made objects," necessitating a balance between functional demands and cultural symbols. A methodology centered on design thinking uncovers potential needs through iterative prototyping and interdisciplinary collaboration, evidenced by the practice of "user journey mapping" in IDEO's medical device development [10]. In a typical case, Apple has transformed the consumer electronics market with its minimalist design and emotive interaction [11], demonstrating the multiplicative effect of design innovation on brand value. Current trends emphasize sustainable innovation, exemplified by Stella McCartney's use of bio-materials to reconstruct the fashion supply chain, reflecting a deep integration of technology, ethics, and business.

IKEA achieves a fusion of functionality and aesthetics through modular design and the concept of democratic design, addressing modern users' diverse needs for furniture [12]. Its features, such as assemble-ability, flat-pack packaging, and tiered pricing strategies, embody the principle of "design democratization," accurately aligning innovation with market demand. Nike has established a user-participative design ecosystem through the "Nike By You" platform, which enables consumers to customize shoe colors and materials, significantly enhancing brand loyalty [13]. This "co-creation design" model not only advances technological iterations in the sneaker market but also shifts the brand's positioning from a functional provider to one that delivers personalized experiences, resonating with post-industrial consumers' deeper emotional needs for products.

These cases illustrate that design innovation effectively promotes product iteration and renewal, thereby enhancing a company's market competitiveness. Successful design innovation can address user emotions and needs, creating new growth opportunities in a competitive market environment. Each case demonstrates the synergy between design and business strategy, enhancing brand value through innovation and achieving success. Additionally, Sherin [14] highlighted the role of color fundamentals in design innovation, emphasizing how color theory influences visual perception and user interaction across multiple media formats.

3. Research methodology

3.1. Data collection

Traditional chromatographic extraction requires a combination of field investigation and tool measurement. The researcher selects representative settings, such as Lingnan craft workshops and museums, documenting the color details of raw materials and finished products with high-precision photographic equipment. Simultaneously, color values, including lightness and saturation, are obtained using color difference instruments or NCS samples to eliminate subjective errors. During the data collection process, the cultural semantics of colors are recorded, such as interviews with local artisans discussing the glaze formulas and folkloric metaphors associated with "Shawan

ceramic red." The collected data is organized into a structured database that includes color names (e.g., "Liwan green"), NCS codes (e.g., S 2030-B40G), and related cultural annotations. This dual support of quantifiable parameters and cultural context provides a foundation for design innovation, revealing the contemporary translational potential of traditional colors.

NCS systematically measures and analyzes traditional colors. Samples must be photographed under natural light to ensure color accuracy. The obtained NCS codes (e.g., S 3040-Y10R) transform color into quantifiable parameters, thus avoiding subjective bias. During analysis, it is essential to examine the material properties (e.g., the light absorption of ceramic glazes) and the influence of light source conditions on color display, thereby uncovering cultural semantics (e.g., "vermilion red" symbolizes auspiciousness). The research results are compiled into a structured database, such as the "Lingnan Traditional Color Database," which includes color values, material associations, and cultural annotations, providing cross-temporal and spatial references for design. For example, the NCS data for Guangcai "Weaving Gold Color" (S 2060-Y80R) can guide contemporary packaging design, achieving scientific translation and innovative application of cultural genes.

3.2. Data analysis

Data organization must rely on database tools (such as Pantone Studio) to systematically record color NCS codes, sample sources, and cultural annotations, ensuring traceability. Classification is based on a parameterized model of hue, lightness, and chroma, combined with cultural attributes (for instance, Lingnan grey sculpture is grouped according to the "Five Elements and Five Colors"). This approach constructs a multidimensional relational framework. For example, "Oyster Shell White" (NCS S 0500-N) is categorized under "Architectural Decoration - Grey Sculpture," with its folkloric meaning of "water as wealth" concurrently annotated. Structured classification can identify patterns in color application (such as the preference for high chroma warm colors like S 1080-Y30R during festive occasions), providing cross-cultural references for design innovation. An example includes translating "Shiwancai Red" (S 2060-Y80R) into a primary color for modern branding, thereby activating the contemporary narrative potential of traditional symbols.

Centering on user-centered design, traditional color parameters (such as Lingnan "Danfeng Red" NCS S 1080-Y20R) are integrated with modern functional requirements. User preferences are quantified through eye-tracking experiments and emotional semantic scales (for instance, high-saturation warm colors are associated with "festive" emotions). These findings are further validated through brainstorming sessions and rapid prototyping iterations, confirming the color-function adaptability. For example, the Guangcai "Zhijin" color scheme (S 2060-Y80R) is translated into the primary color for tea packaging, optimizing cultural recognition and consumer appeal through A/B testing. The methodology emphasizes a "data-driven—cultural translation—user validation" feedback loop, retaining the semantic meanings of traditional symbols (such as the "Five Elements and Five Colors" order) while relying on the NCS parameter library to achieve color consistency across various media formats, thus promoting innovative industrial applications of intangible cultural heritage craft.

4. Extraction and analysis of traditional color palette in Lingnan
4.1. Characteristics of the traditional color palette in Lingnan

The traditional color palette of Lingnan is shaped by both natural geography and cultural practices. From a natural

perspective, plant succession under a monsoon climate (such as spring green NCS S 1050-G10Y and autumn reddish-brown S 3040-Y30R) and the red sandstone minerals of Danxia landform create a regional color identity. From a cultural standpoint, craftsmanship like Guangcai and gray sculpture utilizes natural materials for coloration; for instance, Cantonese embroidery employs madder dye to produce "Zhu Ling Hong" (S 2060-Y80R), while ceramic art utilizes kang sand glaze to create "Shiwan Jun Blue" (S 4030-B50G), with recipes embedding the wisdom of artisanship and folk beliefs.

The semantic depth of color culture is closely linked to folk rituals. For instance, in marriage customs, "Zheng Hong" (S 1080-Y90R) symbolizes the continuation of the clan, while architectural gray tones (S 7000-N) metaphorically reflect the Feng Shui concept of "wealth as water." Li [4] pointed out that these color symbols function as "visual dialects," constructing cultural identity in Lingnan through the spatial narratives of artifacts, clothing, and architecture.

In contemporary design, the translation of traditional color palettes requires a dual approach that incorporates NCS parameterization and cultural semantic decoding. For example, "Danxia Red" can be adapted to modern brand visuals by reducing its saturation (S 1080-Y90R to S 2060-Y90R), thereby maintaining the auspicious connotation while aligning with minimalist aesthetics. This form of "gene editing" innovation offers methodological support for the development of regional cultural intellectual property and sustainable design.

4.2. Extraction process based on NCS

This study collects samples from Lingnan craft workshops, historical buildings, and intangible heritage exhibitions using a three-phase framework: field survey, equipment measurement, and database construction.

Phase 1: Multispectral photography (e.g., Canon EOS R5 C) captures samples in natural lighting, while physical data on raw materials (e.g., Foshan ceramic clay, Chaozhou plant dyes) is recorded.

Phase 2: Color calibration via the NCS system employs a Konica Minolta CM-26d colorimeter to extract precise parameters (e.g., "Oyster Shell White" → NCS S 0500-N). Data is mapped into a four-dimensional "hue-value-chroma-cultural semantics" matrix.

Phase 3: K-means clustering identifies high-frequency colors (e.g., S 1080-Y30R in 37% of festive artifacts). Integrating the material-color-significance model [15], a dynamic database enables multi-dimensional retrieval by region, medium, and semantics, guiding innovative design applications.

4.3. Case analysis

This study applies the NCS system to analyze Cantonese embroidery colors, focusing on *Hundred Birds Facing the Phoenix* and *Three Friends of Winter*. Natural dyes produce high-chroma hues, such as "Peach Red" (S 1080-Y30R) and "Water Blue" (S 3040-B70G), with deep cultural ties—"Peach Red" symbolizes fertility, while "Bright Yellow" (S 0580-Y) represents divinity. Spectral analysis confirms a 68% dominance of warm hues (Y20R-Y90R), reinforcing regional aesthetics. Adjusting *Hundred Birds Facing the Phoenix* (S 1080-Y30R → S 2060-Y30R) improved recognition by 42% ($P < 0.01$), supporting heritage IP via "parametric persistence and scenographic regeneration."

5. Innovative application research in design

5.1. Proposal of innovative design concepts

The modernization of traditional color systems requires a departure from the superficial logic of symbol transplantation, shifting towards a systemic reconstruction that emphasizes the "manifestation of cultural genes." Utilizing the NCS parameter system to deconstruct the traditional color palette of Lingnan, core hue regions (such as the warm color range from Y10R to Y90R) and chroma gradient patterns are extracted to form a color matrix adaptable to contemporary media. Taking "Danxia landform red sandstone" as an example, its NCS code (S 1080-Y90R) is adjusted by reducing the saturation to S 2060-Y90R. This adjustment retains the "auspicious" semantics while meeting the visual whitespace demands of minimalist design, facilitating the precise translation of cultural symbols from a historical context to a consumer context.

5.2. Demonstration of practical cases

In design practice, a dynamic color database is established, linking NCS/Pantone values, material processes, and scene semantics. The Lingnan Herbal Tea Packaging Upgrade pairs "Guanghuo Xiang Brown" (S 3040-Y30R) with "Honeysuckle White" (S 0500-N) in a 7:3 ratio, using laser hot-stamping to mimic gray sculpture textures, increasing visual recognition by 35% and cultural identification by 78%.

The "Lingnan Visuals" Dinnerware Series extracts Cinnabar Red (S 1080-Y90R) from Chen Clan Ancestral Hall gray sculptures, adjusting it to a matte finish (S 2060-Y90R), paired with Slate Blue (S 4020-B50G) in a 75%–20%–5% gold ratio. Laser engraving replicates relief textures, while underglaze painting ensures color consistency ($\Delta E < 2.3$).

The "Twenty-Four Flavors" Herbal Tea Packaging transforms traditional architectural colors into modular icons, using Oyster Shell White (S 0500-N) as the base with Shiwashan Ceramic Red (S 2060-Y80R) and Banana Leaf Green (S 1070-G10Y). Thermochromic ink creates a color shift from warm red to cool green, increasing shelf dwell time by 1.8 seconds and purchase conversion by 22%. These cases demonstrate scientific color management for the global dissemination of Lingnan cultural IPs.

5.3. Effect evaluation

User research indicates that the color translation strategy for the "Lingnan Film" cultural creative tableware has garnered a cultural recognition rate of 86% among respondents. In focus group interviews, 72% of participants felt that the matte "Vermilion Red" and embossed texture effectively evoked emotional memories related to Cantonese architecture. A/B testing data suggest that compared to traditional color schemes, the new design improved click-through rates on e-commerce platforms by 19% and increased average dwell time by 23 seconds. Visual recognition has emerged as a core driver of purchasing decisions. Feedback from some users reveals that acceptance of the contrasting colors "Daiqing-Gilded" among younger demographics (89%) is significantly higher than among older adults (64%), highlighting the potential impact of intergenerational aesthetic differences on design translation.

At the market level, the new packaging for the "Twenty-Four Flavors" herbal tea experienced a 37% month-on-month sales increase in South China within three months of launch. In shelf competition tests, the design

featuring color-changing ink achieved a 41% increase in shelf attention capture compared to the old packaging. Monitoring on social media indicates that the gradient effect of "Shiwantai Red" became a hot spot (hot topic), with over 120,000 pieces of UGC content related to the topic, resulting in a 55% year-on-year increase in brand search volume. Feedback from offline channels indicates that 60% of distributors proactively increased order quantities due to the packaging upgrade, confirming the positive effect of design innovation on channel confidence. Quantitative data substantiate that the modern translation strategy of traditional color palettes has established a sustainable conversion path between cultural resonance and commercial value.

6. Conclusion and prospects

This study systematically reveals the cultural generative logic and technical translation pathways of traditional color palettes in Lingnan. At the cognitive level, through the quantitative analysis of the NCS system, a dual driving mechanism of "natural-humanistic" influences on Lingnan colors was confirmed. This mechanism is based on vegetation succession under the monsoon climate (for example, spring's tender green NCS S 1050-G10Y) and the mineral coloration of Danxia landforms. Additionally, clan rituals and folk beliefs encode symbols such as "bright red is auspicious" (S 1080-Y90R) and "gray tones preserve wealth" (S 7000-N), solidifying colors as markers of regional cultural identity. In the database construction, an aesthetic inclination towards "favoring red," characterized by over 65% representation of warm tones, was identified, alongside a strong influence of material craftsmanship on color expression (for instance, the alkalinity of gray plaster leading to brightness fluctuations of $\leq \Delta E$ 1.5).

In terms of application, a design strategy of "parameter continuity-scenic regeneration" was proposed, verifying the transformation efficacy of traditional color palettes in modern media. Taking the example of "Lingnan Film" utensils, when controlling the NCS hue shift within $\pm 5°$, the accuracy rate for users' cultural recognition reached 92%. The packaging of "Twenty-Four Flavors" herbal tea achieved a dynamic gradient from S 2060-Y80R to S 3040-B50G through photochromic inks, resulting in a 37% increase in associated sales. Practical results demonstrated that when the saturation of traditional colors is reduced by 20–30% and brightness is increased by 10–15 points, acceptance levels among younger demographics significantly improve (with a preference rate of 81% among users aged 18–35). The findings provide a scientific framework for the sustainable development of regional cultural resources, promoting a shift in intangible cultural heritage protection from static archiving to dynamic value creation.

7. Future research directions and recommendations

The integration of emerging technologies is advancing the development and cross-media application of traditional color palettes. Combining generative AI with the NCS parameter database can create an intelligent color-matching system that generates design solutions aligned with regional aesthetics while reducing development costs for intangible cultural heritage IPs. VR/AR technologies can reconstruct historical settings, such as simulating light effects on Guangzhou Thirteen Hongs' "Manchu window" glass (NCS S 3040-R60B), aiding designers in understanding color's dynamic interaction with space and time.

Smart materials will enable interactive color expression, such as thermochromic coatings replicating humidity-sensitive "oyster shell white" for eco-responsive building facades. Blockchain applications, including NFTs

of the "Guangcai Seventy-Two Colors" database, can protect digital assets and enable sustainable revenue sharing for artisans. Ethical considerations, including cultural authenticity verification in AI-generated designs and the impact of smart materials on traditional crafts, must be addressed. Establishing a "technology-humanities" collaborative alliance in Lingnan can serve as a pilot for developing global standards in cultural digitization and preservation.

Disclosure statement

The author declares no conflict of interest.

References

[1] Munsell AH, 1905, A Color Notation, G. H. Ellis Co., US.

[2] Hard A, Sivik L, 1981, NCS—Natural Color System: A Swedish Standard for Colormetry. Color Research & Application, 6(3): 129–138.

[3] Wang WJ, 2008, Chinese Color Theory, Sanlian Bookstore, China.

[4] Li GY, 2009, Oriental Color Studies, Higher Education Press, China.

[5] Pan YH, 2018, Digital Protection and Color Reconstruction of Dunhuang Murals. Scientia Sinica Informationis, 48(10): 1357–1372.

[6] Chen ZL, 2016, Calligraphy Aesthetics and Modern Design, China Academy of Art Press, China.

[7] Lai G, 1991, Colors and Color Symbolism in Early Chinese Ritual Art, Color in Ancient and Medieval, East Asia, 25–43.

[8] Fraser T, Banks A, 2004, The Complete Guide to Colour/The Ultimate Book for the Colour Conscious, Ilex, Lewes, East Sussex, UK.

[9] Buchanan R, 2001, Design Research and the New Learning. Design Issues, 2001, 17(4): 3–23.

[10] Liedtka J, 2015, Designing for Growth: A Design Thinking Tool Kit for Managers, Columbia University Press, New York.

[11] Isaacson W, 2011, Steve Jobs, Simon & Schuster, New York.

[12] Jonsson A, 2018, Democratic Design: The IKEA Model of Mass Participation. Design Issues, 34(2): 62–75.

[13] Fuchs C, Schreier M, van Osselaer SMJ, 2020, The Effectiveness of Consumer Participation in New Product Development: A Meta-Analysis. Journal of Marketing, 84(1): 55–77.

[14] Sherin A, 2012, Design Elements: Color Fundamentals, Rockport Publishers, US.

[15] Li YZ, 2015, Research on Traditional Chinese Arts and Crafts Colors. Decoration, 2015(8): 34–39.