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# Impact of Cultural Congruence in Aesthetic Patterns on User Acceptance of Smart Textiles: A Comparative Study of Chinese Xiangyun and Western Art Nouveau Motifs

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## Article

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## ABSTRACT

*This research addresses a critical challenge in textile functionalization: integrating interactive properties with aesthetic surface treatments to enhance user acceptance in global apparel markets. The study focuses on the fabrication and evaluation of interactive textile samples. A 100% cotton knit fabric substrate underwent surface modification via screen printing, using a thermochromic system based on leuco dyes with an activation temperature of 31°C. To investigate the influence of aesthetics on the reception of the final textile product, two culturally distinct patterns were utilized: a traditional Chinese Xiangyun motif and a Western Art Nouveau floral motif. The performance and user perception of these functionalized fabrics were assessed through a user study involving 60 participants from East Asian and Western cultural backgrounds. Quantitative analysis (two-way ANOVA) of the finished textiles' perceived attractiveness, commercial viability (divided into general purchase intention and willingness to pay a premium), and affective response revealed a significant crossover interaction ( $p < 0.001$ ,  $\eta p^2 = 0.749$ ) between the aesthetic pattern design and the user's cultural background. The findings provide empirical evidence that, while the novelty of the thermochromic feature was universally engaging, it acted as a value amplifier only when the aesthetic base was culturally congruent. Crucially, the willingness to pay a premium for the smart functionality was significantly higher only for the congruent designs, suggesting that aesthetic resonance is a prerequisite for monetizing technical innovation. This study demonstrates that distinct cultural archetypes serve as decisive "visual codes" in user acceptance, challenging the "one-size-fits-all" approach in smart textile design.*

## KEYWORDS

*smart textiles, thermochromic textiles, screen printing, aesthetic pattern design, perceived attractiveness*

## INTRODUCTION

The field of textile engineering has entered a revolutionary era, marked by the convergence of material science, electronics, and design, giving rise to smart textiles and wearable technology [1]. These advanced materials are no longer passive substrates but active interfaces capable of sensing, reacting, and communicating with the user and their environment [2,3]. Applications range from biomedical monitoring and athletic performance tracking to interactive fashion and personal thermal regulation. Despite significant technological advancements and projected market growth, the widespread adoption of smart textiles faces a critical, non-technical barrier: a pervasive lack of emotional connection and cultural relevance [4,5]. Current research and development have predominantly focused on optimizing functionality, power efficiency, and durability, often resulting in products perceived as technologically cold, aesthetically generic, and culturally agnostic. This technology-centric approach overlooks the profound role that textiles have historically played as carriers of cultural identity, personal expression, and aesthetic value [6-8].

The transition from traditional textiles to smart textiles involves a paradigm shift from a static medium to a dynamic, interactive one [9]. However, this transition frequently creates a cultural and aesthetic void [5,10]. When technology is merely superimposed onto a textile without thoughtful integration, it can disrupt the material's inherent semiotic language, cultivated over centuries [5,11]. The aesthetic and symbolic qualities of clothing and textiles are not trivial; they are fundamental to how individuals construct and communicate their identity. Neglecting these deep-seated cultural connections can lead to poor user acceptance, regardless of the technology's sophistication. The core problem this research addresses is the gap between the functional potential of smart textiles and their cross-cultural appeal. A device, no matter how intelligent, will fail to achieve mass adoption if it does not resonate with users on a personal, cultural, and aesthetic level [6,12]. The challenge, therefore, is not merely to make textiles smarter, but to make them more "human" by embedding them with meaning that transcends pure functionality.

This paper proposes that a key mechanism for bridging this gap lies in the strategic and symbiotic integration of traditional aesthetics into the design of smart textiles. Traditional aesthetics, comprising motifs, patterns, and color palettes developed within specific cultural contexts, serve as powerful, non-verbal communication systems. They evoke a sense of familiarity, heritage, and belonging. We hypothesize that when these familiar visual cues are harmoniously fused with the interactive capabilities of smart materials, the resulting product is not only more attractive but also elicits a more positive affective response and fosters a stronger sense of personal connection. This synergy transforms the smart textile from a mere "gadget" into a meaningful

artifact. The interactive technology ceases to be an alienating feature and instead becomes a medium through which the traditional aesthetic is animated and brought to life in a novel way.

To empirically investigate this proposed mechanism, this study undertakes a focused and controlled experiment. We specifically explore the impact of integrating two distinct, culturally significant aesthetic styles—a traditional Chinese motif and a classic Western motif—onto a thermochromic textile. Thermochromic materials, which change color in response to temperature, provide an ideal platform for this investigation, as the interactive element (color change) can be directly and visually linked to the aesthetic pattern itself. By measuring and comparing the responses of participants from both Eastern and Western cultural backgrounds to these prototypes, this research aims to provide quantifiable evidence of the role of cultural aesthetics in user acceptance. The objective is to move beyond speculative discourse and establish a data-driven foundation for a more culturally aware and “human-centric” approach to smart textile design, ultimately contributing to the development of wearable technologies that are not only intelligent but also culturally and emotionally resonant.

## **THEORETICAL FRAMEWORK AND LITERATURE REVIEW**

The conceptual foundation of this study is built upon an interdisciplinary synthesis of theories from material science, human-computer interaction (HCI), cross-cultural design, and Kansei engineering. The literature reveals a growing consensus that the success of wearable technology is contingent on factors beyond technical performance, yet empirical studies directly linking specific aesthetic strategies to cross-cultural user acceptance in smart textiles remain scarce [13-15].

From a material science perspective, the development of functional inks and printable electronics has been a primary enabler of smart textiles [16,17]. Thermochromic materials, in particular, have been explored for applications in safety apparel, fashion, and thermoregulation. The work of Seeboth et al. on the chemistry of leuco dye-based thermochromic systems provides a fundamental understanding of their activation mechanisms and stability, which are critical for reliable application in textiles [18]. Similarly, research in textile engineering has focused on optimizing the application process, such as screen printing and inkjet printing, to ensure durability and colorfastness on various fabric substrates [19]. However, this body of literature is almost exclusively focused on the material properties and manufacturing processes, with little to no consideration for how the visual output of these materials is perceived by end users from different cultural backgrounds. The aesthetic potential is often mentioned but rarely systematically investigated.

In the realm of HCI and wearable computing, the Technology Acceptance Model (TAM) has been a dominant framework, positing that perceived usefulness and perceived ease of use are the primary determinants of user acceptance [20]. While valuable, the original TAM and its subsequent iterations have been criticized for their limited capacity to account for hedonic, aesthetic, and emotional factors, which are particularly salient for wearable items [21]. As wearables become more integrated into daily life and personal expression, their role shifts from that of a tool to that of apparel. This shift necessitates a theoretical lens that extends beyond pure utility. Norman's theory of emotional design, which categorizes user experience into visceral, behavioral, and reflective levels, provides a more holistic perspective [6]. Our research focuses on the visceral (initial aesthetic appeal) and reflective (cultural meaning and self-identity) levels, arguing that these are powerfully influenced by the integration of familiar aesthetic patterns.

The field of cross-cultural design provides the most direct theoretical underpinning for this study. Hofstede's cultural dimensions theory has long been a cornerstone, explaining variations in values and behaviors across national cultures. However, its direct application to product aesthetics can be overly simplistic. A more relevant line of inquiry is found in the study of cultural semiotics, which examines how signs and symbols are interpreted differently across cultures [22]. A pattern is not merely a decoration; it is a signifier laden with culturally specific meanings. For instance, the dragon motif carries vastly different connotations in Eastern and Western cultures. Recent work in cross-cultural HCI has started to address these nuances, advocating for culturally aware design that respects and reflects local values and aesthetics [23]. Yet, much of this work has concentrated on digital interfaces (websites, software) rather than the tangible, material interfaces of smart textiles. This study aims to translate these principles of cultural awareness from the digital to the physical and material domain.

Finally, Kansei engineering, a methodology originating in Japan, offers a practical framework for connecting emotional responses (Kansei) to specific design elements. It seeks to quantify the user's subjective feelings and translate them into concrete design parameters. By employing semantic differential scales to capture affective responses—such as generic vs. personal or technical vs. organic—our methodology draws directly from the principles of Kansei engineering. We adapt this approach to a cross-cultural context, investigating how the same design element (e.g., a curve, a color) embedded within a culturally significant pattern can evoke different Kansei across two distinct user groups. By integrating the material science of thermochromics, the user-centered principles of HCI, the contextual awareness of cross-cultural design, and the affective measurement techniques of Kansei engineering, this study establishes a robust and multi-faceted theoretical

framework to systematically explore the proposed communication mechanism.

## MATERIALS AND METHODS

This study employed a quasi-experimental design to investigate the influence of culturally specific aesthetics on user acceptance of smart textiles. The methodology was designed to ensure scientific rigor, replicability, and the collection of both quantitative and qualitative data.

### Materials

The base substrate selected for all prototypes was a 100% white cotton knit fabric (180 g/m<sup>2</sup>). Cotton was chosen for its widespread use in apparel, good printability, and familiar tactile properties, which minimize the introduction of confounding variables related to fabric hand-feel. The active component was a commercially available, water-based thermochromic ink slurry containing leuco dyes. The ink was specified to have a reversible color transition from black to translucent at an activation temperature of 31°C ± 1°C. This temperature was deliberately chosen as it is close to human skin temperature, allowing for intuitive and direct interaction through touch. A standard textile screen-printing binder and thickener were mixed with the ink slurry according to the manufacturer's specifications to achieve the appropriate viscosity for the printing process.

*Rationale for Achromatic Reversible Transition:* The selection of a black-to-translucent thermochromic system was driven by two methodological imperatives. First, scientifically, the achromatic (black-white) contrast eliminates hue preference as a confounding variable, ensuring that user responses are attributed solely to the morphological features and cultural semantics of the pattern itself. Second, semiotically, the transition from visible to invisible upon touch was designed to operationalize the concept of embodiment. Instead of the pattern merely changing color (which remains an external surface effect), the fading mechanism visually suggests that the cultural motif serves as a temporary interface that dissolves into the user's body upon contact. This creates a metaphor of the user absorbing the cultural symbol, rather than merely observing it.

### Aesthetic Pattern Design and Prototype Fabrication

Two distinct aesthetic patterns were designed to represent Eastern and Western cultural heritages.

*Prototype A (Traditional Chinese Xiangyun Motif):* A seamless pattern was created based on the traditional Chinese *Xiangyun* (祥云), or "auspicious cloud," motif. This motif is deeply rooted in Chinese culture,

symbolizing luck, heaven, and spiritual transformation. The design featured stylized, interlocking cloud spirals. To ensure the internal validity of the experiment, the two patterns were engineered to possess comparable morphological properties. Quantitative analysis was performed on the binary digital masks using ImageJ software. First, Euclidean Distance Map (EDM) analysis showed that the mean line width was consistent between the Xiangyun ( $\bar{w} \approx 1.85$  mm) and Art Nouveau ( $\bar{w} \approx 1.92$  mm) motifs, with similar width variability ( $SD \approx 0.4$ – $0.5$  mm). Second, the Pixel Coverage Ratio (PCR) was controlled within a narrow range (28.4%–30.1%) to equalize the amount of thermochromic ink deposition. Finally, the box-counting method confirmed that both patterns exhibited comparable geometric complexity ( $FD \approx 1.43$  vs. 1.46). While these quantitative metrics ensure physical and optical comparability, specific stylistic nuances in curvature and rhythm were intentionally retained to preserve the authentic cultural identity of each motif.

*Prototype B (Western Art Nouveau Motif):* For the Western counterpart, a pattern inspired by the Art Nouveau movement of the late 19th and early 20th centuries was developed. The selection of the Art Nouveau style was a deliberate methodological choice over other potential Western motifs (e.g., Celtic knots, Greco-Roman patterns) for two primary reasons. First, its characteristic use of long, sinuous, and organic floral lines provided a strong aesthetic counterpart to the curvilinear nature of the Xiangyun motif, helping to control for fundamental visual elements beyond cultural origin. Second, considering the heterogeneity of the Western participant group (comprising North American and European backgrounds), Art Nouveau was selected as a representative of pan-Western visual heritage rather than a specific national identity. While Art Nouveau originated in Europe, its stylistic influence permeated Western graphic design, architecture, and popular culture throughout the 20th century. Therefore, distinct from the exotic nature of the Xiangyun motif for Westerners, the Art Nouveau style serves as a proximal cultural stimulus—an aesthetic that, even if not part of the participants' daily lived experience, is recognizable as part of their broader historical and educational canon.

The fabrication process was standardized for both prototypes. Both patterns were digitally prepared and transferred to a 120-mesh-count screen. The thermochromic ink mixture was applied to the cotton fabric using a manual flat-bed screen-printing technique. A consistent squeegee pressure and angle were maintained to ensure uniform ink deposition. After printing, the fabric samples were air-dried for 24 hours and then heat-cured in a convection oven at 130°C for 3 minutes to fix the ink and ensure washability and durability. The final prototypes were 20 cm × 20 cm fabric swatches, appearing as black patterns on a white background at room temperature (<31°C).

## Participants

A total of 60 unpaid volunteers participated in the study. They were recruited from a university community to ensure a diverse yet controlled demographic. The participants were divided into two groups based on their self-identified cultural background:

- Group 1 (East Asian): 30 participants (15 male, 15 female; mean age = 24.5 years, SD = 2.8) who were born and had lived in an East Asian country (e.g., China, South Korea, Japan) for at least the first 18 years of their lives.
- Group 2 (Western): 30 participants (15 male, 15 female; mean age = 25.1 years, SD = 3.2) who were born and had lived in a Western country (e.g., USA, Canada, UK, Germany) for at least the first 18 years of their lives. It is acknowledged that this grouping encompasses diverse subcultures; however, for the purpose of this study, they serve as a macro-cultural cohort sharing a generalized Western educational and aesthetic background, distinct from the East Asian cohort.

All participants reported having normal or corrected-to-normal vision and no color blindness. An initial screening questionnaire confirmed that participants had a general interest in technology and fashion but no specialized expertise in textile engineering or smart materials, thus representing a target consumer population.

## Experimental Procedure

The experiment was conducted in a controlled laboratory setting with consistent ambient lighting and temperature (22°C). Each participant was tested individually in a session lasting approximately 20 minutes.

The procedure was as follows:

*Informed Consent:* Participants were briefed on the general purpose of the study (evaluating textile designs) without revealing the specific focus on culture or smart properties to avoid bias. They provided written informed consent.

*Phase 1: Visual Evaluation (Static State):* Each participant was presented with the two prototypes, A and B, placed side by side. The order of presentation (left/right) was counterbalanced across participants to control for order effects. Participants were asked to visually inspect the patterns in their inactive (black) state.

*Phase 2: Tactile Interaction (Dynamic State):* The experimenter then instructed the participant to place their hand on each fabric swatch for 10–15 seconds. This direct contact with body heat activated the thermochromic effect, causing the black pattern to fade and reveal the white background beneath, creating

an animated disappearing effect.

*Phase 3: Questionnaire Administration:* Immediately after interacting with both prototypes, participants were asked to complete a questionnaire.

*Phase 4: Semi-Structured Interview:* After the questionnaire, a brief semi-structured interview was conducted to gather qualitative feedback, asking open-ended questions such as, “What did you think of the color-changing effect?” and “Did either of these patterns remind you of anything?”

### **Data Collection and Analysis**

Quantitative data were collected using a questionnaire comprising three key constructs, measured on a 7-point Likert scale (1 = Strongly Disagree, 7 = Strongly Agree):

*Perceived Attractiveness (PA):* Three items (e.g., “This pattern is visually appealing,” “The design is beautiful,” “I find this pattern attractive”).

*Commercial Viability Measures:* To rigorously distinguish between aesthetic adoption and perceived technical value, two distinct metrics were assessed:

1. General Purchase Intention (GPI): Measured by the item “I would consider buying a product with this design,” reflecting the baseline aesthetic acceptance.
2. Willingness to Pay Premium (WPP): Measured by the item “I would be willing to pay a premium for this interactive feature,” capturing the specific perceived economic value of the thermochromic functionality.

*Affective Response (AR):* Assessed using a 7-point semantic differential scale with three bipolar adjective pairs: “Generic—Personal,” “Cold—Warm,” and “Boring—Interesting.”

The reliability of the multi-item scales was confirmed using Cronbach’s alpha, with all constructs exceeding the acceptable threshold of 0.70.

The collected quantitative data were analyzed using IBM SPSS Statistics 26. The primary statistical method was a series of  $2 \times 2$  mixed-design analyses of variance (ANOVA), with Aesthetic Design (Prototype A vs. Prototype B) as the within-subjects factor and Cultural Group (East Asian vs. Western) as the between-subjects factor. This analysis allowed for the examination of the main effects of design and culture, as well as the crucial interaction effect between them. The significance level was set at 0.05. Qualitative data from the interviews were transcribed and subjected to thematic analysis to identify recurring themes and enrich the quantitative findings.

## RESULTS

It is important to clarify the temporal nature of the evaluation. Participants completed the questionnaire immediately after the tactile interaction, meaning their assessment of Perceived Attractiveness represents a cumulative post-experience evaluation. This procedural sequence was designed to maximize ecological validity, mimicking a real-world retail encounter where visual inspection is followed by tactile verification before a final judgment is formed. Therefore, the attractiveness scores reported below reflect a holistic judgment of the design-in-use, integrating both the initial visual impact of the static pattern and the aesthetic delight of its dynamic transformation.

However, interpreting the divergence in attractiveness scores requires looking beyond a simple additive model. While the thermochromic mechanism was physically identical across prototypes and rated universally highly on the interest scale, its psychological impact was not uniform. We posit that the dynamic interaction functioned as an “affective amplifier” rather than a constant variable. In line with the “halo effect,” the high interest generated by the technology likely interacted with the static aesthetic judgment. For the culturally congruent patterns, the interesting technology amplified the positive aesthetic valence, resulting in high attractiveness scores. Conversely, for the incongruent patterns, the same technology failed to rescue the low aesthetic baseline, suggesting that aesthetic resonance acts as a prerequisite “gating factor.” The variance in final scores, therefore, reflects the interaction between the technological novelty and the static cultural semantics, where the static design determines the *direction* (valence) of the preference, and the technology influences the *magnitude* of the experience.

### Perceived Attractiveness (PA)

The two-way ANOVA conducted on the Perceived Attractiveness scores yielded a significant interaction effect between Aesthetic Design and Cultural Group,  $F(1, 58) = 173.42$ ,  $p < 0.001$ ,  $\eta^2 = 0.749$ . The magnitude of this effect size ( $\eta^2 = 0.749$ ) should be interpreted as a specific function of the Culture  $\times$  Archetype interaction. The experiment utilized highly prototypical stimuli (Xiangyun vs. Art Nouveau) designed to serve as high-contrast visual codes. Consequently, the statistical result does not imply a generalized divergence in all aesthetic preferences, but rather demonstrates that when presented with distinct cultural archetypes, the participants’ cultural background acts as a decisive determinant. The effect is thus strictly operationalized as the interaction between cultural identity and specific symbolic archetypes. It is critical to note that this effect size should not be evaluated against generic behavioral science benchmarks (where  $\eta^2 > 0.14$  is typically

classified as large). In the context of this mixed-design experiment, the high value is structurally inflated by two factors: the removal of inter-subject variability inherent to the repeated-measures design, and the high signal-to-noise ratio of the controlled sensory discrimination task. Thus, the metric reflects the precision of the experimental control rather than a generalized predictive strength for real-world consumer behavior. Given this substantial effect size, a post-hoc power analysis was conducted using G\*Power 3.1 software. The analysis indicated that the achieved statistical power ( $1 - \beta$ ) for detecting the interaction effect exceeded 0.99, far surpassing the standard acceptable threshold of 0.80. This statistical validation confirms that despite the sample size of  $N = 60$ , the experimental design possessed ample sensitivity to reliably detect the cross-cultural differences with negligible risk of Type II errors.

As illustrated in Figure 1, the East Asian group rated Prototype A (*Xiangyun* motif) significantly higher in attractiveness ( $M = 6.31, SD = 0.62$ ) than Prototype B (Art Nouveau motif) ( $M = 3.45, SD = 0.84$ ). Conversely, the Western group rated Prototype B significantly higher ( $M = 6.42, SD = 0.57$ ) than Prototype A ( $M = 3.61, SD = 0.91$ ). Simple effects tests confirmed that these differences were statistically significant for both groups ( $p < 0.001$ ). This crossover interaction strongly supports the hypothesis that attractiveness is mediated by cultural familiarity with the aesthetic.

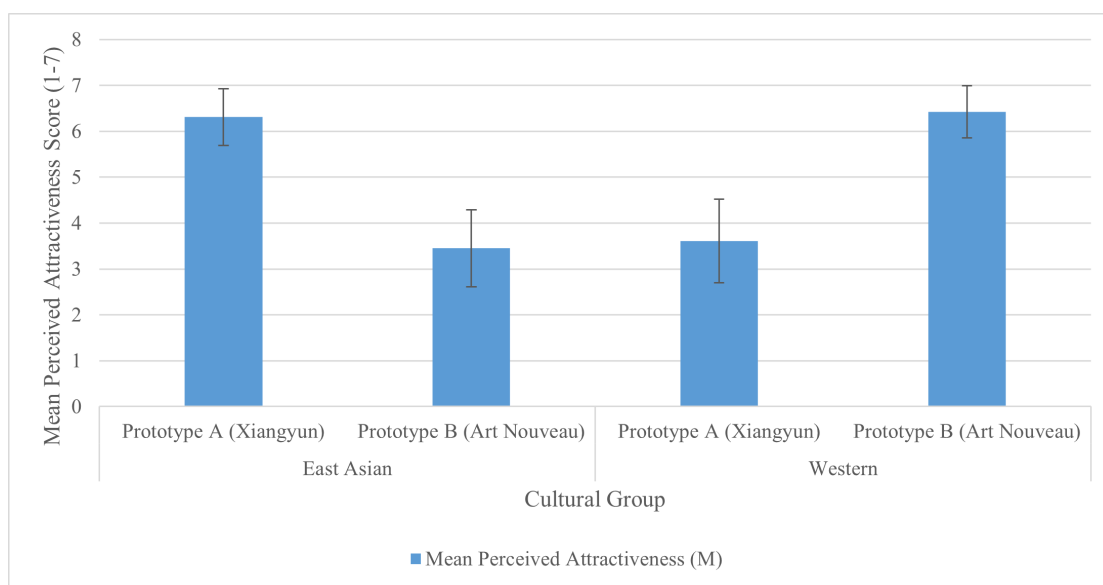


Figure 1. Mean Perceived Attractiveness Scores by Cultural Group and Prototype Design

## Purchase Intention (PI)

### *General Purchase Intention (GPI)*

The analysis of GPI mirrored the attractiveness results. As expected, East Asian participants expressed significantly higher purchase intention for the culturally congruent Xiangyun motif, while Western participants favored the Art Nouveau motif. This confirms that aesthetic preference directly drives baseline market demand.

### *Willingness to Pay Premium (WPP)*

Crucially, the analysis of WPP revealed that the economic value of the smart technology was partially mediated by cultural congruence. Participants were significantly more willing to pay a premium for the thermochromic feature only when it was integrated into a pattern they found culturally relevant (see Table 1). For the incongruent patterns, despite finding the technology interesting, the willingness to pay extra dropped significantly. This distinction highlights that technical novelty alone is insufficient to drive high-value consumption without aesthetic resonance.

Table 1. Mean Scores and Standard Deviations for Study Variables

Variable	Cultural Group	Prototype A (Xiangyun)	Prototype B (Art Nouveau)
Perceived Attractiveness	East Asian	M = 6.31, SD = 0.62	M = 3.45, SD = 0.84
	Western	M = 3.61, SD = 0.91	M = 6.42, SD = 0.57
General Purchase Intention (GPI)	East Asian	M = 6.05, SD = 0.92	M = 3.15, SD = 1.08
	Western	M = 3.35, SD = 1.15	M = 6.12, SD = 0.85
Willingness to Pay Premium (WPP)	East Asian	M = 5.71, SD = 1.05	M = 2.75, SD = 1.18
	Western	M = 2.95, SD = 1.25	M = 5.78, SD = 0.95
Affective Response (Generic– Personal)	East Asian	M = 6.15, SD = 0.85	M = 3.20, SD = 1.05
	Western	M = 3.35, SD = 0.95	M = 6.25, SD = 0.75
Affective Response (Cold– Warm)	East Asian	M = 6.05, SD = 0.90	M = 3.50, SD = 1.15
	Western	M = 3.60, SD = 1.00	M = 6.10, SD = 0.80

## Affective Response (AR)

The analysis of the semantic differential scales revealed a similarly strong interaction for the Generic—Personal and Cold—Warm dimensions.

*Generic vs. Personal:* A significant interaction was found,  $F(1, 58) = 51.98, p < 0.001, \eta^2 = 0.472$ . Participants from both groups rated their culturally congruent design as significantly more Personal. An East Asian participant commented on Prototype A, stating, “This feels familiar, like something from my grandmother’s house, but modern. It feels like it’s for me.” A Western participant said of Prototype B, “It’s elegant and classic, a style I recognize and love. The other one feels foreign.”

*Cold vs. Warm:* The interaction effect was also significant. The culturally familiar patterns were perceived as affectively warmer. This effect was enhanced by the thermochromic function. A participant noted, “Touching it and having it react to my warmth made the familiar pattern feel alive and responsive, which was a very warm feeling.”

*Boring vs. Interesting:* Interestingly, there was no significant interaction effect for this dimension,  $F(1, 58) = 2.09, p = 0.152$ . However, there was a significant main effect of Aesthetic Design, as both groups rated both prototypes highly on the Interesting scale (all means  $> 5.8$ ). This suggests that the novelty of the thermochromic technology itself was engaging to all participants, regardless of the pattern printed on it. A Western participant who disliked the *Xiangyun* pattern still remarked, “I don’t like the design, but the way it disappears is really cool. It’s very interesting.”

## Qualitative Insights

Thematic analysis of the interview transcripts corroborated the quantitative findings. Two major themes emerged:

*Cultural Resonance as a Gateway to Acceptance:* Participants consistently used words like familiar, nostalgic, elegant, and meaningful to describe their preferred, culturally congruent design. The patterns were not seen as mere decoration but as carriers of cultural value, which made the technology feel more approachable and desirable.

*Synergy between Aesthetics and Technology:* The thermochromic effect was perceived not as a separate gimmick but as an enhancement of the pattern. Participants described the interaction as magical, playful, and surprising. Crucially, this positive technological experience was amplified when the pattern itself was already appreciated. For the non-preferred pattern, the effect was deemed “interesting but not for me,” whereas for

the preferred pattern, it was “amazing, I want this.” This highlights a synergistic relationship where appealing aesthetics and novel technology mutually reinforce each other to create a superior user experience.

## DISCUSSION

The results of this study provide robust empirical evidence for the central hypothesis: the integration of the specific, culturally resonant aesthetics used in this study is a powerful mechanism for enhancing user acceptance of smart wearable textiles across different cultures. The statistically significant interaction effects observed across perceived attractiveness, purchase intention, and affective response metrics demonstrate that user preference is not universal but is deeply mediated by cultural background. This moves the conversation about smart textile design beyond pure functionality and into the crucial domains of cultural semantics and emotional connection. The findings challenge the prevalent “one-size-fits-all” approach to wearable technology design and underscore the necessity of cultural customization.

The core mechanism at play appears to be a combination of cognitive fluency and cultural identity affirmation. The culturally congruent patterns were processed with greater ease (cognitive fluency) by participants, leading to an immediate and intuitive positive visceral response, as predicted by emotional design theory. Participants did not need to consciously analyze the *Xiangyun* or Art Nouveau motifs; they recognized them on a subconscious level, which evoked feelings of familiarity and comfort. This fluency contrasts sharply with the experience of viewing the culturally foreign pattern, which required more cognitive effort to process and was often perceived as simply other. Furthermore, by embedding symbols of cultural heritage into a piece of advanced technology, the prototypes served to affirm the user’s cultural identity. Several participants expressed a sense of pride in seeing their traditional art forms being used in a modern, innovative context. This reflective response, where the object connects to one’s self-image and heritage, creates a much deeper and more enduring bond than one based on technological novelty alone.

A particularly salient finding is the synergistic relationship between the traditional aesthetic and the smart function. The analysis of the Boring—Interesting scale showed that the thermochromic technology was universally perceived as interesting. However, this interest only translated into strong purchase intention and a feeling of personal connection when paired with a desirable aesthetic. This implies that technology alone can capture attention, but it is the successful marriage of technology and a culturally meaningful surface pattern that captures the user’s heart and wallet. The color-changing effect was not just a feature; it was an experience that animated the pattern, making a static cultural symbol dynamic and interactive. This

transformation from a passive design to an active interface is a key value proposition of smart textiles, but our results show its ability to drive purchase intention and personal connection is contingent on the underlying aesthetic it animates. Our findings on the Boring—Interesting scale suggest that the novelty of the technology can capture universal interest on its own; however, this interest does not automatically translate to product acceptance. Indeed, a cool technology cannot salvage a culturally alienating *aesthetic pattern*.

This research also has significant practical implications for the textile and wearable technology industries. The findings advocate for a market segmentation strategy based on cultural aesthetics. Instead of creating a single, globally neutral (and often sterile) design, companies could develop design collections tailored to specific cultural markets. This approach, which could be termed “cultural customization” or “aesthetic localization,” could serve as a powerful market differentiator. For example, a global brand could release a smart jacket with an interactive LED matrix, but the default patterns could be based on Celtic knots for the European market, Navajo-inspired geometric patterns for the North American market, and Ukiyo-e-inspired wave patterns for the Japanese market. This would allow the same core technology to be housed within a product that feels personal and relevant to diverse consumer bases.

It is important to acknowledge the limitations of this study. The selection of only one motif to represent each broad cultural category (Eastern and Western) is a necessary simplification for experimental control, but it does not capture the vast diversity within these cultures. A significant limitation lies in the binary classification of Western participants. We treated individuals from North America and Europe as a monolithic cultural group, potentially overlooking the nuances of intra-Western diversity. The Art Nouveau style, while historically significant in Europe, may possess a different degree of resonance for a participant from the American Midwest compared to one from France or Belgium. For the American participants, the preference for Art Nouveau might stem less from cultural identity (“This is who I am”) and more from cultural familiarity (“I recognize this style from Western history”), whereas the East Asian group’s connection to Xiangyun may be more deeply rooted in lived cultural practice. Future research should apply a more granular demographic segmentation to investigate these nuances. It is therefore critical to emphasize that the findings cannot be generalized to imply that all individuals from East Asian backgrounds would prefer any traditional Chinese design over any Western one, or vice versa. The strong interaction effect observed is specific to the Xiangyun and Art Nouveau motifs tested. These results highlight a principle of cultural familiarity and resonance but do not provide a basis for broad Eastern vs. Western aesthetic generalizations. Future research is essential to explore how other motifs from these and other cultures are perceived. Future research should explore a

wider range of traditional aesthetics and subcultures, extending beyond the controlled laboratory setting and fabric swatches utilized in this study. The perception and acceptance of these designs might differ when they are incorporated into a complete garment and used in a real-world context over a prolonged period. Longitudinal studies are needed to assess long-term engagement and the potential for novelty to wear off. Finally, regarding the sampling demographics, we acknowledge the reliance on a university student cohort ( $N = 60$ ). However, we argue that this specific demographic characteristic serves to strengthen, rather than weaken, the validity of our core finding regarding cultural resistance. University students typically represent a WEIRD (Western, Educated, Industrialized, Rich, Democratic) population segment that is characterized by higher openness to experience and cosmopolitanism compared to the general public. If a significant cultural congruence bias is observable even in this relatively open-minded and tech-savvy demographic, it is plausible that similar or potentially stronger effects may emerge in more conservative consumer segments, although this hypothesis requires direct empirical validation. Therefore, the cultural boundaries observed in this study likely represent a conservative baseline. While the absolute magnitude of the interest scores might be slightly inflated by the students' familiarity with technology, the direction and significance of the aesthetic preference effect are robust. Future studies extending to diverse socioeconomic cohorts would likely verify and potentially amplify these boundaries. A limitation of this study concerns the quantification of aesthetic equivalence. Although we controlled for global visual complexity using fractal dimension and pixel coverage ratio, subtle differences in local feature distribution and curvature rhythm—inherent to the distinct cultural styles—could not be entirely eliminated without compromising the authenticity of the motifs. Future research could employ eye-tracking technology to investigate whether these micro-level stylistic variations result in different visual scanning paths or cognitive loads, independent of cultural background. Finally, the operationalization of the PI construct warrants discussion. Our scale combined an item measuring the intent to buy a product with a specific design with another item assessing the willingness to pay a premium for the interactive feature. This approach risks conflating preference for the static aesthetic with the perceived value of the technology, potentially leading to scale contamination. Our rationale for combining them was to capture a holistic measure of commercial intent for the final, integrated product as a consumer would encounter it. However, we concede that future research would be strengthened by measuring these as separate constructs to more clearly distinguish the value drivers attributable to the design versus the interactive function.

### **Semiotic Density and Cultural Decoding**

A critical distinction in this comparative study lies in the ontological nature of the visual stimuli. While the quantitative analysis confirmed that the Xiangyun and Art Nouveau motifs were equivalent in terms of syntactic properties (fractal dimension, line width, and pixel coverage), they differ significantly in their semantic density. The Xiangyun motif functions as a specific iconographic symbol with a high-context strong code in Chinese culture, carrying explicit metaphysical meanings of auspiciousness and divinity. In contrast, the Art Nouveau motif functions primarily as a stylistic signifier, representing a broader Western aesthetic heritage rather than a singular discrete concept.

This semantic asymmetry was a deliberate experimental condition. By rigorously controlling the physical visual variables (the signifier's form), we isolated the symbolic strength (the signified's weight) as the primary independent variable. The study's results suggest that for the East Asian group, the high symbolic density of the Xiangyun pattern triggered a deeper cognitive resonance that transcended mere aesthetic appreciation. This indicates that in smart textile design, user acceptance is driven not just by looking good (stylistic congruence) but by meaning something (semiotic resonance). The Art Nouveau pattern, lacking this specific iconic intensity for the Eastern group, failed to bridge the gap between technological novelty and emotional connection.

### **The Economics of Aesthetic Resonance**

By analyzing GPI and WPP as distinct constructs, this study uncovers a nuanced consumer psychology in the smart textile market. While GPI aligns predictably with cultural preference, the WPP data offers a novel insight: the smart feature acts as a "value multiplier" only when the aesthetic base is secure.

Our results indicate that consumers do not evaluate the utility of the thermochromic function in isolation. Instead, the willingness to pay a premium is contingent upon the host aesthetic. When the pattern is culturally incongruent, the technology is perceived merely as a gimmick—interesting but not valuable. However, when the pattern resonates culturally, the technology is perceived as an enhancement, justifying a higher price point. This suggests that, in the context of fashion-oriented wearables, cultural relevance is not just a design preference but a prerequisite for monetizing technical innovation.

## CONCLUSION

This study set out to investigate the cross-cultural communication mechanism of smart wearable textiles that integrate traditional aesthetics. Through a controlled experiment involving thermochromic textile prototypes and participants from East Asian and Western cultural backgrounds, we have demonstrated that culturally congruent aesthetics are not merely decorative additions but are fundamental prerequisites for monetizing technical innovation. The data reveal that, while the technological novelty of the smart textile was universally appreciated, it functioned primarily as an affective amplifier rather than a standalone value driver. Crucially, our analysis of commercial viability distinguishes between interest and value. While the interactive effect captured universal attention, this interest converted into a willingness to pay a premium only when coupled with a culturally resonant surface pattern. This implies that, in the cognitive processing of smart textiles, specific cultural archetypes serve as the necessary “semantic anchor.” Without this cultural resonance, the technology remains a gimmick; with it, the technology transforms into a value-added feature that revitalizes traditional forms. This multiplicative interaction model challenges the industry’s techno-centric focus, proving that cultural meaning is the gateway to economic value.

For the textile industry and the burgeoning wearables market, this study provides a clear directive: to succeed globally, design locally. The future of wearable technology does not lie solely in inventing more powerful sensors or more efficient batteries, but in a deeper understanding of how these innovations can be woven—both literally and figuratively—into the rich and diverse fabric of human culture. Future research should expand upon this framework, exploring a wider array of cultural aesthetics, smart functions, and user demographics to build a more comprehensive and nuanced understanding of the intersection between material innovation and cultural identity.

### *Availability of Data and Materials*

The datasets used and/or analysed during the current study were available from the corresponding author on reasonable request.

### *Author Contributions*

Yuwei Zhang and Jun Xu designed the study; all authors conducted the study; Jun Xu and Yuwei Zhang collected and analyzed the data. Yuwei Zhang and Jun Xu participated in drafting the manuscript, and all authors contributed to critical revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published. All authors participated fully in the work, took public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or completeness of any part of the work were appropriately investigated and resolved.

### *Ethics Approval and Consent to Participate*

This survey was conducted in compliance with Ethics Committee of Chongqing Health College. Participants were informed of the study's purpose and data usage prior to participation, and responses were collected anonymously. No personally identifiable information was stored.

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### *Conflict of Interest*

The authors declare no conflict of interest.

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