Textile & Leather Review

ISSN 2623-6281| www.tlr-journal.com | 10.31881/TLR

# Silk and Music: Visual and Auditory Experiences Interwoven with Cultures

Biao Yan

**How to cite:** Yan B. Silk and Music: Visual and Auditory Experiences Interwoven with Cultures. Textile & Leather Review. 2026; 9:136-153. https://doi.org/10.31881/TLR.2026.136

**How to link:** https://doi.org/10.31881/TLR.2026.136

**Published:** 23 January 2026

# Silk and Music: Visual and Auditory Experiences Interwoven with Cultures

**Biao YAN**

Department of Film and Television, School of Animation and Media, Qingdao Agricultural University, Qingdao City 266109, Shandong Province, China

byan78@126.com

**Article**

https://doi.org/10.31881/TLR.2026.136

*Received 25 September 2025; Accepted 27 October 2025; Published 23 January 2026*

**ABSTRACT**

*This study systematically investigates the acoustic properties of woven silk fabrics to establish a material science basis for their performance in functional applications. The sound absorption coefficients of textiles constructed from continuous-filament mulberry silk (charmeuse and gauze weaves) were quantitatively characterized and benchmarked against staple-fiber cotton and synthetic polyester fabrics. The research methodology combined standardized textile acoustic testing (ISO 10534-2, with a 50 mm air cavity) with perceptual evaluation in a semi-anechoic environment. Results demonstrate that the inherent fiber morphology and fabric construction of silk charmeuse yield superior sound absorption performance, particularly in the 1,000–4,000 Hz range—a key metric for functional acoustic textiles. This measured physical property was strongly correlated with psychoacoustic assessments, in which the silk fabric structure effectively mitigated high-frequency acoustic reflections. The findings provide a quantitative characterization of a natural protein fiber-based textile, demonstrating how its hierarchical structure, from fibroin polymer to final woven fabric, dictates its efficacy as a high-performance technical textile for specialized acoustic management.*

**KEYWORDS**

*silk fabrics, acoustic properties, sound absorption, functional fabrics, natural fibers*

## INTRODUCTION

The confluence of material culture and artistic expression has perpetually shaped human experience, creating rich tapestries of sensory and symbolic meaning [1,2]. Within this landscape, the pairing of silk and music stands as a particularly resonant and enduring example of cross-modal aesthetic harmony. Historically, in contexts ranging from the imperial courts of ancient China, where musicians performed in flowing silk robes surrounded by ornate tapestries, to the opulent opera houses of Baroque Europe with their silk-laden interiors, this lustrous textile has served as the material counterpart to sophisticated auditory art [3-5]. This relationship is deeply embedded in cultural consciousness, often articulated through the language of luxury, elegance, and refinement. Silk's visual appeal—its unique sheen, vibrant color affinity, and graceful drape—is seen as a fitting visual environment for the ephemeral beauty of music [6]. However, this traditional understanding, rich as it may be, rests almost entirely on a foundation of historical observation and aesthetic appreciation. A critical gap exists in the scientific literature regarding the functional, physical basis of this connection. The question of whether silk's role is purely that of a passive, symbolic backdrop, or whether it actively contributes to the quality of the auditory experience through its inherent material properties, has yet to be rigorously investigated. This leaves a fascinating intersection of textile engineering, acoustics, and cultural studies largely unexplored [7,8].

This paper aims to address this lacuna by proposing and testing a central thesis: that the celebrated cultural synergy between silk and music is not solely a product of aesthetic convention but is significantly reinforced by the unique and favorable acoustic properties of silk textiles. We posit that the material composition and microstructure of silk fibers, and the fabrics woven from them, give rise to specific acoustic behavior that can enhance the listening experience—particularly for music characterized by intricate detail and complex harmonic content. To move beyond anecdotal evidence and provide a robust, empirical foundation for this claim, this study adopts a focused and quantitative research design. We have selected the traditional Chinese zither, the *Guqin*, as an exemplary case study. This choice is deliberate: the *Guqin*'s performance philosophy prizes clarity, subtlety, and a rich palette of tonal color, including delicate harmonics and nuanced finger sounds. While its fundamental tones typically lie in a low range (approximately 65 Hz to 523 Hz), its characteristic timbre and transient finger noises are defined by a prominent series of high-order harmonics with significant spectral energy within the 1,000–4,000 Hz range. Furthermore, its historical performance context—the intimate scholar's studio—was an environment frequently rich in silk textiles, from wall scrolls to garments. This research systematically quantifies the sound absorption characteristics of different silk fabrics and compares them to those of other common textiles. Subsequently, it measures the direct impact of these materials on the subjective, psychoacoustic perception of *Guqin* music in a controlled laboratory setting. By providing replicable, data-driven evidence, this study endeavors to build a scientific bridge between a centuries-old cultural practice and the principles of modern material science, offering novel insights into the performance of heritage materials and suggesting their untapped potential in the field of contemporary acoustic design.

## THEORETICAL BACKGROUND AND LITERATURE REVIEW

### The Hierarchical Structure and Properties of Silk

Silk, a natural proteinaceous fiber, is distinguished by its remarkable combination of mechanical strength and aesthetic appeal. Its primary constituent, fibroin, possesses a complex hierarchical structure that is key to its properties [9,10]. At the molecular level, fibroin consists of long-chain amino acids dominated by glycine, alanine, and serine, which are organized into crystalline β-sheet regions and amorphous domains [11]. These β-sheets, acting as nanocrystalline reinforcements, are responsible for silk's high tensile strength, while the amorphous regions impart flexibility and elasticity [12]. These molecules assemble into nanofibrils, which in turn bundle to form the core fibroin filament [11]. This filament, extruded by the *Bombyx mori* silkworm, has a characteristic triangular cross-section with rounded apices [13]. This non-circular geometry is the primary source of silk's unique optical properties, causing light to scatter and reflect in a way that produces its signature luster [14].

When these continuous filaments are woven into fabric, they create a multi-scale porous structure. The intra-yarn porosity is determined by the packing of individual filaments, while the inter-yarn porosity is a function of the weave architecture (e.g., plain, satin, twill) and the thread count [15]. From an acoustics standpoint, three parameters of this porous structure are critical: porosity, tortuosity, and flow resistivity. Porosity (Ø) is the fraction of air volume within the material [16]. Tortuosity ($\tau$) describes the convolutedness of the pathways through the pores, with higher tortuosity forcing air particles to travel a longer path. Flow resistivity ($\sigma$) measures the resistance the material presents to the passage of air. For a textile, these parameters are dictated by fiber diameter, fiber packing density, and fabric construction. The smooth, continuous, and relatively uniform filaments of silk create a different type of porous network compared to fabrics made from staple fibers like cotton or wool, which are composed of short, irregular, and crimped fibers [17]. This structural difference is hypothesized to lead to distinct acoustic behaviors.

### Physics of Sound Absorption in Fibrous Materials

The primary function of an acoustic absorber is to dissipate incident sound energy, primarily by converting it into heat [18]. In porous materials like textiles, this conversion occurs through several mechanisms as a sound wave propagates into the fibrous matrix. The dominant mechanisms are viscous and thermal losses [16]. As the sound wave causes the air within the material's pores to oscillate, friction occurs between the oscillating air molecules and the stationary fiber surfaces [19]. This viscous drag, or boundary layer effect, converts kinetic energy into low-grade heat. Simultaneously, the adiabatic compression and rarefaction of the air within the pores create temperature gradients between the air and the solid fiber material. The subsequent heat transfer from the air to the fibers during compression, and back during rarefaction, is an irreversible thermodynamic process, resulting in further energy loss [19].

The efficacy of a porous absorber is highly frequency-dependent. At low frequencies, the large wavelengths of sound mean the air within the material tends to move in phase with the incident wave, resulting in minimal absorption [20]. As frequency increases, the wavelength becomes comparable to the material's thickness and pore dimensions, leading to greater velocity gradients and thermal exchange, thus increasing the sound absorption coefficient, $\alpha$ [20]. This coefficient typically peaks at a frequency where the material's thickness is approximately one-quarter of the sound's wavelength. Empirical models, such as the Delany-Bazley model, provide a framework for predicting the acoustic impedance and propagation constant of porous materials based on their flow resistivity [19,20]. While widely used for conventional acoustic materials, the applicability of these models to complex, anisotropic structures like woven silk fabrics requires specific investigation.

**Psychoacoustics of Musical Quality Perception**

Psychoacoustics bridges the gap between objective, physical measurements of sound and the subjective experience of a human listener. In the context of room acoustics, key objective measures like Reverberation Time (RT60), Early Decay Time (EDT), Clarity Index ($C_{80}$), and Interaural Cross-Correlation Coefficient (IACC) have been shown to correlate strongly with perceived auditory quality [21]. The Clarity Index ($C_{80}$), for example, is the logarithmic ratio of the energy in the first 80 milliseconds of a room's impulse response to the energy arriving later. It is a strong indicator of perceived musical clarity and definition. IACC measures the similarity of signals arriving at a listener's two ears, correlating with the perceived "spaciousness" or "envelopment" of the sound field [21,22].

The subjective attributes used in this study—"Clarity," "Warmth," "Intimacy," and "Harshness"—are well-established perceptual descriptors. "Clarity" relates directly to the listener's ability to distinguish individual notes, timbral details, and musical lines [23,24]. Intimacy, the subjective sense of being close to the performers, is strongly correlated with a high ratio of direct-to-reverberant sound energy and a short initial time delay between the direct sound and the first significant reflections. “Warmth” is typically linked to a rich and full bass response (approximately 125–250 Hz). “Harshness,” conversely, is a negative attribute often caused by excessive or spectrally unbalanced high-frequency reflections, leading to a sound that is perceived as sharp, brittle, or fatiguing. For an instrument like the *Guqin*, whose sonic signature includes not only fundamental tones but also a complex array of high-frequency harmonics and transient noises from fingering techniques, the control of high-frequency reflections is paramount to achieving its desired aesthetic of refined tranquility [25].

## EXPERIMENTAL METHODOLOGY

A rigorous, two-phase experimental protocol was designed to provide a comprehensive analysis linking the material properties of silk to the human perception of music.

### Material Sample Preparation and Characterization

Four distinct textile types were selected to provide a robust comparative analysis. The samples were chosen to represent different fiber origins, structures, and common applications.

**Silk Charmeuse (SC):** 100% *Bombyx mori* mulberry silk, satin weave. Material weight: 19 momme (82 g/m$^2$). Thread count: 108 × 84 threads/inch. This represents a high-quality, lustrous silk fabric often used in apparel and decorative hangings. To rigorously control for the influence of areal mass, a multi-layer configuration was prepared. Three layers of Silk Charmeuse were stacked without adhesive bonding to form the three-layer Silk Charmeuse stack (SC3L) sample. This configuration achieved a total areal density of 246 g/m$^2$ and a measured thickness of 0.80 mm. Based on a standard silk fiber density of 1.33 g/cm$^3$, the calculated porosity of this stack is approximately 77%. This setup allows for a direct comparison where differences in acoustic performance can be attributed to fiber morphology and pore structure rather than mass alone.

**Silk Gauze (SG):** 100% *Bombyx mori* mulberry silk, plain weave. Material weight: 8 momme (35 g/m$^2$). Thread count: 60 × 52 threads/inch. This represents a lightweight, acoustically transparent silk.

**Cotton Twill (CT):** 100% cotton staple fiber. Material weight: 270 g/m$^2$. Thread count: 96 × 64 threads/inch. The sample thickness was measured at 0.52 mm. With a fiber density of 1.54 g/cm$^3$, the calculated porosity is approximately 66%, indicating a significantly more compact and less porous structure compared to the multi-layer silk stack.

**Polyester Velvet (PV):** 100% polyester pile weave. Material weight: 350 g/m$^2$. A synthetic textile frequently used in theatrical and acoustic applications for its known absorptive qualities.

Prior to any testing, all fabric samples were conditioned for a minimum of 48 hours in a standard environmental chamber maintained at 21 ± 1°C and 65 ± 2% relative humidity, in accordance with ASTM D1776 standards. The detailed physical specifications and calculated microstructural parameters for all tested samples are summarized in Table 1.

Table 1. Physical Properties and Calculated Microstructural Parameters of the Tested Fabrics

| Sample | Areal Mass (g/m²) | Thickness (mm) | Fiber Density (g/cm³) | Calculated Porosity (ϕ) |
|---|---|---|---|---|
| Silk Gauze (SG) | 35 | 0.15 | 1.33 | 82.5% |
| Silk Charmeuse (SC) | 82 | 0.27 | 1.33 | 77.1% |
| Three-layer Silk Charmeuse stack (SC3L) | 246 | 0.80 | 1.33 | 76.9% |
| Cotton Twill (CT) | 270 | 0.52 | 1.54 | 66.3% |
| Polyester Velvet (PV) | 350 | 1.80 | 1.38 | 85.9% |

Note: Porosity is calculated as ϕ = (1 - $\rho_{fabric}/\rho_{\text{fiber}}$)×100%.

## Objective Acoustic Property Measurement

The normal incidence sound absorption coefficient ($\alpha$) was determined using the two-microphone transfer function method as specified by ISO 10534-2. A Brüel & Kjær Type 4206 impedance tube apparatus was employed. Circular samples with diameters of 100 mm and 29 mm were precisely cut from each fabric type to accommodate the low-frequency (100–1,600 Hz) and high-frequency (1,600–4,000 Hz) measurement tubes, respectively. To simulate the typical application of silk as a draped hanging or curtain, the samples were mounted with a defined air cavity of 50 mm separating the fabric from the rigid reflective backing plate. This setup allows for the formation of standing waves within the cavity, positioning the resistive fabric layer at a location of high particle velocity for specific frequency bands, thereby maximizing absorption efficiency according to the quarter-wavelength principle. The sound source, a loudspeaker at the opposite end of the tube, generated a broadband pink noise signal. The complex acoustic transfer function between two ¼-inch condenser microphones (Brüel & Kjær Type 4187) placed at fixed positions along the tube was measured using a PULSE multi-analyzer system. Prior to testing, a microphone phase and amplitude calibration was performed using the standard two-microphone switching technique (sensor-swapping) as specified by the standard. The driving signal was broadband pink noise, and the analyzer was set with a 16.384 kHz sampling frequency, 800 spectral lines, and 50 averages to ensure a high signal-to-noise ratio. The results from the low- and high-frequency tubes were then combined to generate the final absorption spectrum. From this transfer function, the complex reflection coefficient and subsequently the normal incidence sound absorption coefficient ($\alpha$) were calculated in one-third octave bands over a frequency range of 100 Hz to 4,000 Hz. To ensure statistical reliability, five distinct samples of each fabric type were tested, and the results were arithmetically averaged.

**Subjective Perceptual Study**

A double-blind, repeated-measures listening experiment was designed to assess the subjective impact of the textiles.

**Participants:** Thirty volunteers (15 male, 15 female; mean age = 27.4 years, SD = 5.2) participated in the study. All participants underwent pure-tone audiometric screening to confirm hearing thresholds of 20 dB HL or better in both ears for octave frequencies from 250 Hz to 8,000 Hz. All were non-musicians but reported enjoying instrumental music, ensuring a panel of engaged, non-expert listeners.

**Acoustic Environment and Stimulus:** The experiment was conducted within a semi-anechoic chamber (3.5 m × 4.0 m × 2.8 m) with a measured background noise level below 20 dBA and a baseline RT60 of < 0.1 s. The selection of a semi-anechoic environment with a low baseline RT60 (< 0.1 s) was deliberate. This high-sensitivity setup was designed to eliminate the confounding variables of complex room modes and late reverberation. By creating an acoustically neutral background, the experiment isolated the perceptual impact of the single reflective surface (11.2 m²). Consequently, any perceived differences in clarity or timbre could be unequivocally attributed to the specific absorption characteristics of the test materials interacting with the direct first-order reflections, rather than generalized room reverberation. A single wall (surface area 11.2 m²) was designated as the treatment surface. In the Control condition, this surface consisted of the chamber's standard wall construction: painted gypsum board, providing a hard, acoustically reflective baseline. For each of the five experimental conditions (Control, SG, SC3L, CT, and PV), the wall was completely covered with the corresponding textile, mounted flat against the surface. The auditory stimulus was a 60-second anechoic recording of the classic *Guqin* piece "Flowing Water" (*Liú Shuǐ*), chosen for its wide dynamic range and rich textural content. The stimulus was reproduced via a single Genelec 8030A active studio monitor, calibrated to produce an average sound pressure level of 65 dBA at the listener's head position.

**Experimental Procedure:** Participants were seated in a calibrated central listening position. They were presented with the four acoustic conditions in a counterbalanced, randomized order to mitigate order effects. To strictly control for visual bias and ensure a double-blind protocol, an acoustically transparent but visually opaque fabric screen (black speaker grille cloth) was positioned 20 cm in front of the treatment wall. This setup effectively concealed the visual identity of the test materials from the participants while allowing sound waves to propagate through to the test surface with negligible attenuation. Consequently, the participants were unaware of the specific wall condition for any given trial. After listening to the 60-second excerpt in each condition, participants were prompted via a custom software interface to rate their experience on five semantic differential scales anchored from 1 to 7:

- Clarity: (Muddled 1 – 7 Clear)
- Warmth: (Thin/Cold 1 – 7 Full/Warm)
- Intimacy: (Distant 1 – 7 Close/Intimate)
- Harshness: (Smooth 1 – 7 Harsh/Sharp)
- Overall Preference: (Strongly Dislike 1 – 7 Strongly Like)

**Statistical Analysis**

All statistical analyses were performed using IBM SPSS Statistics (Version 28.0). The acoustic measurement data were averaged, and standard deviations were calculated to assess variability. For the perceptual data, a one-way repeated measures analysis of variance (ANOVA) was conducted for each of the five subjective attributes as the dependent variable, with the acoustic condition (Control, SC, CT, PV) as the independent variable. Mauchly's test was used to assess the assumption of sphericity; where violated, a Greenhouse-Geisser correction was applied. Significant main effects from the ANOVA were followed by post hoc pairwise comparisons using a Bonferroni correction to control for Type I errors. The significance level ($\alpha$) was set at 0.05 for all statistical tests. Effect sizes were calculated using $\eta^2 p$.

## RESULTS

### Acoustic Absorption Coefficients

The averaged sound absorption coefficients for the four textile samples are plotted as a function of frequency in Figure 1a and 1b. The results reveal significant differences in the acoustic behavior of the materials.

The PV sample, as anticipated, demonstrated the highest overall absorption, exhibiting a broad peak with $\alpha = 0.80$ in the 600 Hz to 1200 Hz range, making it an effective mid-frequency absorber. The CT showed modest absorption across the spectrum, with a broad, low peak around 1000 Hz and an average of approximately 0.25. The lightweight SG was largely transparent at low frequencies but showed a progressive increase in absorption above 1000 Hz, consistent with its low mass and high porosity.

Most significantly for this study's hypothesis, the SC displayed a unique and compelling acoustic profile. While its low-frequency absorption was moderate, it exhibited a steep and sustained increase in performance from 800 Hz upwards, peaking at $\alpha = 0.68$ at 2500 Hz. Figure 1a illustrates the baseline performance of single-layer SC. To validate the structural advantage under controlled mass conditions, Figure 1b compares the SC3L directly against the CT and PV. As shown in Figure 1b, the three-layer silk stack (SC3L, 246 g/m²) not only matched the low-frequency performance of the CT (270 g/m²) but significantly outperformed it in the 1000–4000 Hz range, achieving a peak coefficient of 0.85 compared to 0.25 for cotton. This indicates a dramatically higher acoustic efficiency per unit mass for the silk structure. This high efficiency for silk in absorbing high-frequency sound energy is critical for musical transients, harmonics, and sibilance.

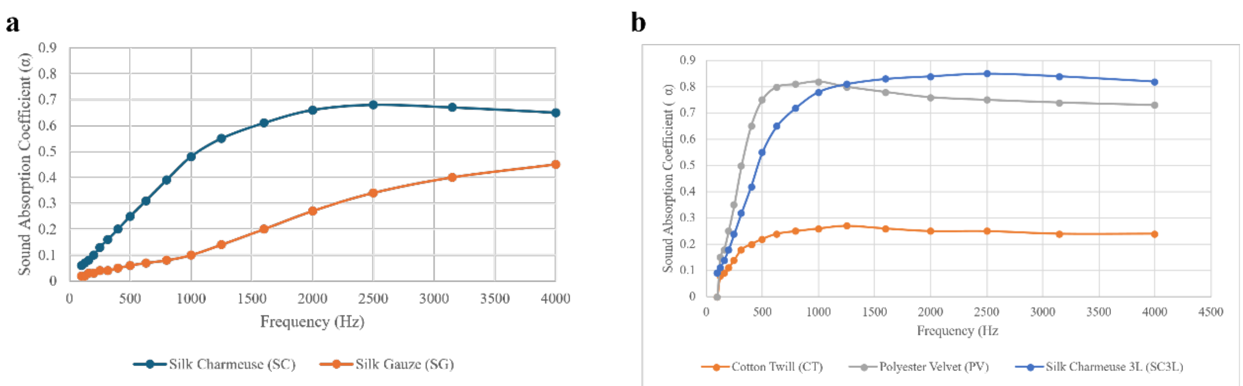


Figure 1. Normal Incidence Sound Absorption Coefficient (α). (a) A direct comparison between SC and SG highlights the influence of fabric construction. (b) Comparison of the mass-controlled SC3L against the CT and PV materials. The SC3L curve demonstrates

that, under the condition of a 50 mm air cavity, the silk structure achieves optimal impedance matching, significantly outperforming cotton of similar mass

## Psychoacoustic Evaluation

The subjective ratings from the 30 participants provided a clear perceptual correlate to the objective acoustic measurements. The mean ratings and standard deviations for each attribute are summarized in Table 2, and the mean ratings are visualized in Figure 2.

Table 2. Descriptive Statistics of Subjective Ratings (Mean ± Standard Deviation)

| Attribute | Control | Silk Gauze (SG) | Three-layer Silk Charmeuse stack (SC3L) | Cotton Twill (CT) | Polyester Velvet (PV) |
|---|---|---|---|---|---|
| Clarity | 4.80 ± 1.21 | 4.92 ± 1.15 | 6.13 ± 0.78 | 5.23 ± 0.97 | 5.90 ± 0.84 |
| Warmth | 4.33 ± 1.12 | 4.38 ± 1.05 | 4.70 ± 0.92 | 4.57 ± 1.01 | 4.93 ± 0.98 |
| Intimacy | 4.47 ± 1.38 | 4.60 ± 1.25 | 5.83 ± 1.05 | 4.90 ± 1.15 | 5.57 ± 1.10 |
| Harshness | 4.53 ± 1.33 | 4.35 ± 1.20 | 2.47 ± 0.90 | 3.80 ± 1.10 | 2.30 ± 0.84 |
| Overall Pref. | 4.27 ± 1.28 | 4.45 ± 1.18 | 6.03 ± 0.85 | 4.87 ± 1.04 | 5.77 ± 0.97 |

The repeated measures ANOVA revealed statistically significant main effects of the acoustic condition on four of the five attributes.

**Clarity:** A significant effect was found, F(3, 87) = 8.92, $p < 0.001$, $\eta^2 p$ = 0.235. Post hoc tests showed that the SC condition was rated significantly clearer than the Control ($p < 0.001$) and CT ($p = 0.008$) conditions.

**Harshness:** There was a highly significant main effect on perceived harshness, F(3, 87) = 15.61, $p < 0.001$, $\eta^2 p$ = 0.350. Both the SC and PV conditions were rated significantly less harsh than the Control ($p < 0.001$) and CT ($p < 0.001$) conditions.

**Intimacy:** A significant effect was observed for intimacy, F(3, 87) = 6.22, $p = 0.001$, $\eta^2 p$ = 0.177. The SC condition was rated as significantly more intimate than the Control condition ($p = 0.002$).

**Overall Preference:** A significant main effect was also found for overall preference, $F(3, 87) = 9.87$, $p < 0.001$, $\eta^2 p = 0.254$. The SC condition was preferred significantly more than both the Control ($p < 0.001$) and CT ($p = 0.005$) conditions. In contrast, the SG condition showed no statistically significant differences from the Control condition for any attribute ($p > 0.05$), indicating a perceptual similarity to the reflective boundary.

**Warmth:** No significant difference was found among the conditions for warmth, $F(3, 87) = 1.95$, $p = 0.128$, indicating that the materials' primary acoustic impact was not in the low-frequency domain.

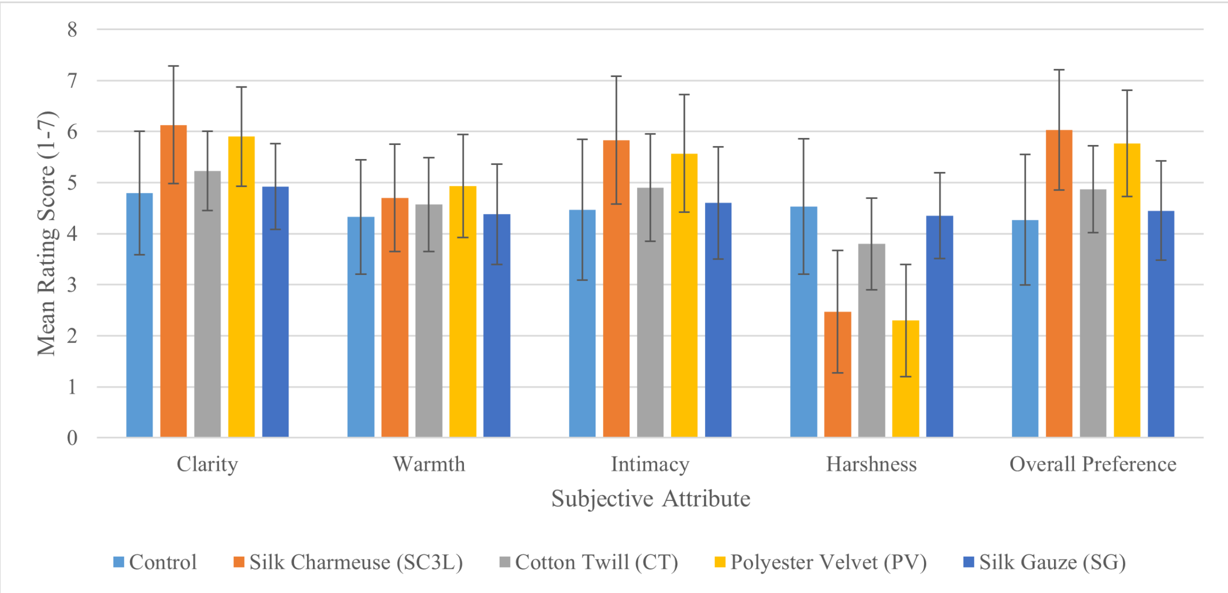


Figure 2. Mean subjective ratings on a 7-point scale for the five acoustic conditions. Error bars represent the 95% confidence interval

## DISCUSSION

The collective results of this study offer compelling support for the central hypothesis: the cultural reverence for silk in musical contexts is deeply rooted in its advantageous and quantifiable acoustic properties. This research successfully demonstrates a causal chain from the material structure of silk to its acoustic function, and from that function to a measurably enhanced human perceptual experience. The discussion first interprets the linkage between the objective and subjective findings, then explores the underlying material science, and finally considers the broader cultural and practical implications.

The strong correlation between the acoustic measurements and the psychoacoustic ratings is the most critical outcome of this research. The superior sound absorption of silk charmeuse in the 1–4 kHz range provides a direct physical explanation for the significantly higher listener ratings in “Clarity” and lower ratings in “Harshness.” This frequency range is instrumental in defining the textural and temporal characteristics of music. For the *Guqin*, this band contains the sharp attack of the string being plucked, the high-order harmonics that define its timbre, and the subtle, fricative sounds of the fingers sliding on the silk strings—sounds that are integral to an expressive performance. In the semi-anechoic setting, the Control condition (painted gypsum) introduced a singular, distinct strong reflection against the silence. For instruments rich in high-frequency transients like the Guqin, this created a harsh “slap-back” effect that masked detail. The Silk Charmeuse treatment effectively mitigated this specific artifact without deadening the sound excessively. Notably, while the room’s low RT60 (< 0.1 s) represents an “extreme” listening environment compared to a typical concert hall, it serves as an ideal proxy for the “Scholar’s Studio” (Shufang) aesthetic. Traditional Guqin performance prioritizes “Intimacy” and “Direct Sound” over the diffuse reverberation of Western performance spaces. The silk material, by cleaning up the harsh first reflection while preserving the warmth of the direct sound, successfully recreated the psychoacoustic distinctiveness of this culturally specific listening tradition—intimate, dry, and detailed. By efficiently absorbing energy in this specific spectral range, the silk charmeuse selectively attenuates high-frequency reflections. This reduction of potentially jarring reverberant energy allows the intricate, transient details of the performance to become more clearly perceptible. This acoustic clarification process is precisely what the listeners perceived and reported as higher “Clarity.”

The significant increase in perceived “Intimacy” is also a direct consequence of the silk’s high-frequency absorption. In psychoacoustics, intimacy is strongly correlated with a high ratio of direct-to-reverberant sound energy. The silk treatment, by effectively attenuating the energy of late-arriving, detail-masking reflections which are rich in high-frequency content, significantly increased this ratio. This physically altered the acoustic environment to give listeners the subjective impression of being closer to the instrument—a key aesthetic goal for *Guqin* performance. This acoustic effect perfectly mirrors the traditional performance goal of the *Guqin*, which is not for a large concert hall but for a close, personal, and contemplative listening experience. The data scientifically validate that a silk-adorned room is not just visually intimate but acoustically intimate as well. While the Chinese scholars who championed the *Guqin* undoubtedly valued silk for its beauty and cultural significance, its inherent acoustic properties would have naturally and fortuitously contributed to achieving the very soundscape their music required: one of tranquility, purity, and clarity.

A compelling aspect of silk charmeuse's performance is its high absorption efficiency, particularly in the high-frequency range, despite its significantly lower areal mass compared to the CT (82 g/m² vs. 270 g/m²). This hypothesis is robustly validated by the results of the mass-controlled experiment. When the silk's mass was increased to match the cotton (SC3L vs. CT), the silk demonstrated decisively superior absorption across the functional frequency spectrum. This confirms that the difference in performance is not an artifact of sample weight or thickness, but stems from the distinct micromorphology of the silk filaments. To further isolate the influence of fabric structure from material composition, the inclusion of SG in the subjective study provided a critical insight. As shown in Table 2, while the SC significantly improved "Clarity" and "Intimacy," the SG showed no statistically significant difference from the Control condition. This contrast effectively proves that the "silk acoustic effect" is not merely a psychological placebo associated with the material's cultural value, but is a tangible physical phenomenon driven by the specific high-density architecture of the satin weave. However, the dramatic absorption peak ($\alpha \approx 0.85$) observed at 2,500 Hz cannot be attributed to fiber morphology alone, given the thinness of the material. Instead, it results from the interaction between the silk's structure and the mounting condition. While the theoretical quarter-wavelength resonance for a 50 mm air cavity is approximately 1,715 Hz, the observed peak frequency is notably higher. This shift suggests that the acoustic behavior is not governed solely by the cavity depth, but is significantly influenced by the fabric's mechanical properties. The key finding is that the SC3L achieves an optimal impedance match within this specific frequency band. Specifically, the high tension of the silk yarns likely introduces a strong membrane resonance effect, which superimposes on the porous absorption to shift the peak efficiency towards 2,500 Hz. As expected from its lower mass, the silk charmeuse offered no significant advantage at low frequencies; the minor variations observed in the absorption coefficients below 500 Hz were not statistically or perceptually significant. This is strongly supported by the psychoacoustic data, which found no statistical difference ($p = 0.128$) in perceived "Warmth" between any of the materials. From a microstructural perspective, the acoustic difference is governed by flow resistivity. The CT, composed of short, crimped staple fibers and a high-twist yarn structure, likely exhibits excessive flow resistivity. With a calculated porosity of only ~66%, the compact cotton surface creates a large acoustic impedance mismatch. This causes the sound waves to be reflected before they can enter the material's pores to be dissipated. In contrast, the SC3L, with its continuous filament structure and significantly higher calculated porosity of ~77%, creates a more organized and open pore network. This structure provides an optimized flow resistivity that matches the impedance of the air in the 50 mm cavity more effectively, allowing high-frequency sound waves to penetrate and dissipate efficiently. It is also important to consider that for such tightly woven, thin fabrics, the acoustic impedance is not solely resistive. The high tension of the silk yarns in the charmeuse weave likely introduces a membrane resonance effect. When superimposed in the SC3L, this effect is amplified, where the vibrating fabric layers dissipate additional energy at specific resonant frequencies, working in tandem with the porous absorption to achieve peak coefficients exceeding 0.80.

While PV showed excellent absorption, it is noteworthy that silk charmeuse achieved comparable subjective preference ratings. This may indicate the existence of an "optimal" level of absorption. Velvet's powerful broadband absorption may have created an environment that, while clean, felt acoustically "dead" or unnatural to some listeners. Silk's more targeted absorption—strong in the problematic high frequencies but more moderate elsewhere—may have struck a more pleasing balance, controlling harshness without eliminating the natural acoustic ambiance that contributes to a sense of envelopment. This positions silk not as a blunt instrument for sound absorption, but as a nuanced tool for acoustic tuning.

This study is not without limitations. A primary challenge in comparative textile acoustics is the inherent variation in areal mass across different weave types. This study addressed this limitation by introducing the mass-controlled SC3L. This inclusion effectively isolated the variable of fiber structure, confirming that the observed acoustic benefits are intrinsic to the silk morphology rather than a byproduct of mass differences. Regarding the microstructural mechanism, while direct airflow resistivity measurements were not performed, the porosity values calculated in this study (77% vs. 66%) provide strong theoretical evidence supporting the proposed model. These calculations align with the acoustic impedance matching theory, suggesting that the continuous filament structure of silk indeed creates a network of finer, more tortuous micro-pores compared to the staple-fiber cotton. Future work employing micro-CT imaging could further visualize these 3D flow paths. The use of normal incidence absorption coefficients provides a standardized comparison but does not fully capture the behavior of materials in a diffuse sound field, which would be better characterized in a reverberation chamber. The study was also limited to a single musical instrument and a specific mounting condition. Furthermore, the perceptual study exclusively used non-expert listeners. While this provides valuable insight into general listener preference, the findings would be substantially strengthened by future research incorporating a comparative panel of trained musicians or *Guqin* performers, who are likely more sensitive to the subtle timbral and textural details that this study hypothesized were being affected. Future work should expand this research to include random-incidence absorption measurements (ISO 354), starting with a comparison of silk to materials of directly comparable weave and density, as well as investigating a wider range of musical genres and instruments and exploring the acoustic effects of draping silk fabrics with an air gap—a common real-world application. Computational modeling, using micro-CT scans to create 3D models of silk weaves, could also be employed to simulate airflow and predict acoustic properties, providing deeper theoretical insight. Finally, considering silk's high value and specialized application, a critical next step is to investigate its performance within multi-layer composite structures. This would involve using silk as a decorative and functional facing fabric over a less expensive, porous core material, transitioning the research from characterization towards practical acoustic engineering. Such work would aim to develop optimized, sustainable acoustic panels for applications where both aesthetic and auditory excellence are required. Despite these avenues for future exploration, the current findings provide a robust and seminal foundation. They recontextualize silk from a purely decorative material into the realm of high-performance technical textiles, offering a sustainable, biodegradable, and aesthetically unparalleled alternative to synthetic acoustic materials in discerning architectural applications.

## CONCLUSION

In conclusion, this interdisciplinary study successfully demystifies the long-standing cultural association between silk and music by grounding it in rigorous scientific evidence. The research has quantitatively demonstrated that silk textiles, particularly dense weaves like charmeuse, possess a distinct and highly effective capacity for absorbing sound energy in the mid-to-high frequency range. This inherent physical property was shown to translate directly into a superior and more refined auditory experience, as evidenced by statistically significant improvements in perceived musical clarity, intimacy, and overall preference in a controlled listening environment. The findings suggest that the historical affinity for silk in musical settings is not merely a matter of aesthetic preference but is supported by a strong functional basis. The material's inherent properties are well-suited to the acoustic requirements of complex, detailed music, providing a scientific explanation for this enduring cultural tradition.

This work makes a significant contribution by bridging the gap between material science, acoustics, and cultural heritage, providing a new lens through which to appreciate the sophisticated material knowledge embedded in historical traditions. By validating the acoustic performance of silk, this study not only illuminates the past but also opens new possibilities for the future. It positions silk as a viable, high-performance, and sustainable material for use in modern architectural acoustics, capable of delivering both exceptional auditory quality and unparalleled visual beauty. Ultimately, this research affirms that, in the cultural tapestry of silk and music, the threads of aesthetic symbolism and scientific function are inextricably and beautifully interwoven.

*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*

Biao Yan designed, collected and analyzed the data, and drafted the manuscript. Biao Yan conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Biao Yan participated fully in the work, take 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 integrity of any part of the work are appropriately investigated and resolved.

*Ethics Approval and Consent to Participate*

This survey was conducted in compliance with Ethics Committee of School of Animation and Media, Qingdao Agricultural University. 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.

*Acknowledgments*

Not applicable.

*Funding*

Not applicable.

*Conflict of Interest*

The author declares no conflict of interest.

**REFERENCES**


[1] Gell A. Art and Agency: An Anthropological Theory. Oxford, England: Clarendon Press; 1998.

[2] Howes D. The Sensory Studies Manifesto: Tracking the Sensorial Revolution in the Arts and Human Sciences. Toronto, ON, Canada: University of Toronto Press; 2022.

[3] Howes D. Empire of the Senses: The Sensual Culture Reader. New York, NY, USA: Routledge; 2021.

[4] Yang X. The Golden Age of Chinese Archaeology: Celebrated Discoveries from the People's Republic of China. London, UK: Yale University Press; 1999. 584 p.

[5] Sargentson C. Merchants and luxury markets: The marchands merciers of eighteenth-century Paris. 1996. 297–301. Available from: http://www.jstor.org/stable/1316046.

[6] Spence C. Crossmodal correspondences: A tutorial review. Attention, Perception, & Psychophysics. 2011; 73(4):971-995. doi: 10.3758/s13414-010-0073-7

[7] Samuel BT, Barburski M, Witczak E, Jasińska I. The influence of physical properties and increasing woven fabric layers on the noise absorption capacity. Materials. 2021; 14(20):6220. doi: 10.3390/ma14206220

[8] Asdrubali F, editor. Green and sustainable porous materials for noise control in buildings: A state of the art. SAPEM-Symposium on the Acoustics of Poro-Elastic Materials; 2011. Available from: https://hdl.handle.net/11391/497297

[9] Brough HD, Cheneler D, Hardy JG. Progress in Multiscale Modeling of Silk Materials. Biomacromolecules. 2024; 25(11):6987-7014. doi: 10.1021/acs.biomac.4c01122

[10] Schaefer C, Laity PR, Holland C, McLeish TC. Silk protein solution: A natural example of sticky reptation. Macromolecules. 2020; 53(7):2669-2676. doi: 10.1021/acs.macromol.9b02630

[11] Qi Y, Wang H, Wei K, Yang Y, Zheng R-Y, Kim IS, et al. A review of structure construction of silk fibroin biomaterials from single structures to multi-level structures. International Journal of Molecular Sciences. 2017; 18(3):237. doi: 10.3390/ijms18030237

[12] Keten S, Xu Z, Ihle B, Buehler MJ. Nanoconfinement controls stiffness, strength and mechanical toughness of β-sheet crystals in silk. Nature Materials. 2010; 9(4):359-367. doi: 10.1038/nmat2704

[13] Chen S, Liu M, Huang H, Cheng L, Zhao H-P. Mechanical properties of Bombyx mori silkworm silk fibre and its corresponding silk fibroin filament: A comparative study. Materials & Design. 2019; 181:108077. doi: 10.1016/j.matdes.2019.108077

[14] Shin KI, Kim SH, Kim JJ. Image analysis of the luster of fabrics with modified cross-section fibers. Fibers and Polymers. 2005; 6(1):82-88. doi: 10.1007/BF02875578

[15] Ogulata RT, Mezarcioz S. Total porosity, theoretical analysis, and prediction of the air permeability of woven fabrics. Journal of the Textile Institute. 2012; 103(6):654-661. doi: 10.1080/00405000.2011.597567

[16] Kalauni K, Pawar S. A review on the taxonomy, factors associated with sound absorption and theoretical modeling of porous sound absorbing materials. Journal of Porous Materials. 2019; 26(6):1795-1819. doi: 10.1007/s10934-019-00774-2

[17] Mather RR, Wardman RH, Rana S. The Chemistry of Textile Fibres. London, UK: Royal Society of Chemistry; 2023.

[18] Everest FA. The Master Handbook of Acoustics. New York, NY, USA: McGraw-Hill; 2001.

[19] Allard J, Atalla N. Propagation of Sound in Porous Media: Modelling Sound Absorbing Materials. Hoboken, NJ, USA: John Wiley & Sons; 2009.

[20] Cox T, d’Antonio P. Acoustic Absorbers and Diffusers: Theory, Design and Application. Boca Raton, FL, USA: CRC Press; 2016. doi: 10.1201/9781315369211

[21] ISO E. 3382, Acoustics–Measurement of room acoustic parameters–Part 1: Performance spaces. Part. Brussels, Belgium: International Organization for Standardization; 2009. p. 69.

[22] Barron M. Auditorium Acoustics and Architectural Design. New York, NY, USA: Spon Press; 2009. doi: 10.4324/9780203874226

[23] Beranek LL. Concert Halls and Opera Houses: Music, Acoustics, and Architecture. Berlin/Heidelberg, Germany: Springer; 2004. doi: 10.1007/978-0-387-21636-2

[24] Siebein GW, Barron M. Auditorium Acoustics and Architectural Design. Noise Control Engineering Journal. 2011; 59(2):213-215.

[25] Van Gulik RH. The Lore of the Chinese Lute. An Essay in Ch'in Ideology. Monumenta Nipponica. 1938; 1(2):386-438. doi: 10.2307/850477