Research Article

Musical transmission and collective memory: A psychocultural study of Tujia folk songs

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ABSTRACT

This psychocultural study explores the relationship between musical transmission and collective memory within the Tujia ethnic minority in China, focusing on the role of traditional folk songs as mnemonic vessels for cultural identity. Using a mixed-methods design across three generational cohorts, the study applies four novel analytical techniques—Multi-Generational Transmission Analysis (MGTA), Digital Cognitive Mapping, Biometric Coding, and Network Analysis—to examine how emotional engagement, symbolic coherence, and social learning contexts shape memory retention. The findings indicate a marked generational decline in cultural knowledge, especially in contextual understanding and symbolic literacy. Emotional synchrony during ritual-based transmission emerged as a strong predictor of memory retention, while institutional instruction showed limited efficacy. Furthermore, most lyrical and symbolic changes reflected cultural erosion rather than creative innovation. The study concludes that sustainable heritage preservation depends not only on documentation but on revitalizing embodied, affective, and community-rooted learning environments that support psychocultural continuity.

Keywords: Tujia folk songs; musical transmission; collective memory; psychocultural; intangible cultural heritage; intergenerational knowledge; China; ethnomusicology; cultural psychology

1. Introduction

The future of the intangible cultural heritage (ICH) depends on the oral traditions, particularly folk music, which relies on healthy intergenerational transfer. Musical replication as opposed to the simple reproduction of sound patterns is a psychocultural device by means of which collective memory is coded, preserved and reinterpreted. Collective memory is the pool of historical experience, value system and community identity that unifies a people [1-3]. On the national census of 2020, the Tujia population was well above 8.3 million people, thus making them one of the 55 constitutionally recognized ethnic minorities in the country. Most of the Tujia people are found in the Wuling Mountains, which is a geographic region spanning western Hunan, southwestern Hubei, northeastern Guizhou and the outskirts of Chongqing Municipality. Their folk song tradition (Tujia min'ge) includes different genres such as labor songs (Lao Dong Ge),

wedding laments (Kū Jia Ge), funeral dirge (Sang Ge) and narrative epics (Shishi Ge). Repertoires also form cultural archives in the sense that they maintain historical accounts, moral traditions, ecological know-how, and shared emotional articulations [4,5].

Even though the Tujia musical tradition is rich in cultural and linguistic levels, it is exposed to extreme tension. The accelerated modernization and the acceleration of urban migration have forced the younger generations out of the rural cultural contexts, and the establishment of Mandarin as the main language of education and media has undermined the linguistic premise on which the lyrical understanding and performance are based [6]. The gradual loss of the customary ritual contexts of performances such as agricultural festivals, ancestor-worship ceremonies, and life-cycle events has reduced the natural environment within which the related songs were once sung and learned. Many field surveys carried out between 2018 and 2022 in western Hunan confirm that less than 20 % of Tujia young people under the age of thirty are able to sing a full traditional folk song without the textual support, but over 80 % of elders 60 years and older continue to do so [7-12]. The repertoires and their social functions have been studied before. However, there still exists a significant gap in relation to the psychocultural processes which clarify the retention, modification, or abandonment of which musical features melodic structures, lyrical narratives, or contextual knowledge are retained, modified, or abandoned in the transmission process.

The problems that have been persistent in the existing research, it is important to create a multilayered psychocultural framework that would combine the knowledge of the collective memory theory [13,14], the ethnomusicology of transmission, and cultural psychology. Based on this framework, the study conceptualizes Tujia folk song transmission as dynamic, embodied and affect charged practice of memory work. The elements of learning, remembering, and reinterpreting songs, which comprise emotional connections, cognitive processes, and actual experiences, were described in this study [15] using a multi-dimensional framework that extends across generations. This theoretical framework provides a foundation for understanding how music is passed down through generations and how memories are kept alive. [16].

Through a multi-method approach that includes ethnography of observation, cognitive recall mapping, biometric emotional assessments, and social network analysis, this study explores the memory-enhancing properties of music and the factors that govern the transmission of specific sets of information from one generation to another [17]. This research contributes to the current literature and offers useful recommendations for heritage policymakers by stating that preservation initiatives should focus on reviving the physical and dynamic systems that maintain and transmit collective memory, in addition to archival conservation [18].

The literature on the topic has focused on the repertoires of Tujia folk songs, intergenerational transmission models and general models of intangible cultural heritage preservation in China. Nevertheless, up to date there is no study which has combined the analysis of the musical transmission processes and the formation of collective memory within the framework of the psychocultural approach. Relevant literature primarily focuses on Tujia folk song repositories, intergenerational transmission models, and general patterns of intangible cultural heritage preservation in China [19,20]. However, these studies often emphasize documentation or performance standardization, with limited integration of psychocultural mechanisms such as emotion, memory, and identity. There is a small empirical body of literature using mixed-methods designs where ethnographic observations, biometric monitoring, network mapping, and cognitive-recall tasks are combined to analyses the embodied performance contexts and semantic depth of Tujia song traditions in multiple generational cohorts simultaneously [21-23].

The Tujia people form one of the most well-known ethnic minorities of China and represent a wide range of folk songs that serve as the living treasuries of historical accounts, moral codes and empirical knowledge of the natural environment. The language has changed to Mandarin and the importance of ceremonial contexts has decreased due to rapid urbanization.

By conducting a thorough analysis of Tujia folk songs, this research fills a gap in our understanding of their possible function in maintaining cultural memory and identity. The objectives around which the paper is based are as follows:

1) Think about participatory, oral, and institutional contexts when trying to understand the transmission of Tujia folk music.

2) Identify cultural memory mnemonics in musical, poetic, symbolic, and contextual components.

3) Analyze the emotional, semantic, and identity-related mechanisms that sustain musical traditions.

4) Create a map of retention, change, and erosion using MGTA, digital cognitive mapping, biometric coding, and network analysis.

5) Model preservation strategies that bring back learning settings that are embodied, emotionally charged, and rooted in their context.

By addressing the research objectives, this study makes the following contributions:

• Theoretical: Integrates musical transmission, collective memory, and psychocultural theories into a unified framework for understanding folk songs as living cultural archives.

• Methodological: Pioneers the combined use of MGTA, Digital Cognitive Mapping, Biometric Coding, and Network Analysis for multi-angle transmission analysis.

• Empirical: Reporting on cross-generational evidence (first-hand) of retention, adaptation and loss in the tradition of Tujia song.

• Policy: Makes sensible suggestions about how to preserve the emotional and contextual integrity of cultural traditions.

• Cross-Cultural: Preserves local and minority cultural practices in a manner that is easily replicated elsewheres.

This paper has 5 sections. The 1st section talks about, research gap, objectives,background and contributions. The 2nd part is a review of literature regarding the Tujia folk song transmission, collective memory, and psychocultural heritage. The 3rd part explains the sampling plan and operationalization of MGTA, Digital Cognitive Mapping, Biometric Coding, and Network Analysis. The 4th part describes and explains results on intergenerational transmission patterns and policy implications. The fifth part ends with some significant insights, contributions, and future research directions.

2. Literature review

2.1. Musical transmission and intergenerational knowledge in Tujia folk songs

Experimental studies of musical transmission and intergenerational knowledge transfer demonstrated that oral traditions are both the product of universal cognitive inclinations and culture-specific narrative structures. Margulis et al. [28] embraced the cross-cultural narrative elicitation to explore the reaction to instrumental music and proved the culture-bounded intersubjectivity in the imagined narratives of the participants, thus proving that the learning of musical information results in marked differences in memory

encoding across sociocultural contexts- a fact that is relevant to the study of Tujia learners' integration of song meaning. Mehr et al. [29] conducted a large, cross-cultural acoustic study that included 315 societies and showed that some categories of songs are universally attested (e.g., dance, lullabies) but show a strong functional and stylistic variation. The paper therefore postulates that despite the core communicative functions of Tujia folk songs, the ornamentation and genre conventions of the songs are culturally specific. During a scalable iterated singing experiment described by Anglada-Tort et al. [30], oral transmission was shown to be biased toward sing ability and structural simplification, a trend that is similar to simplification of Tujia melodies among younger generations. Howard [31] critically analyzed Chinese Dream cultural policy of China through its music-education reforms by noting how strategic adoption of ethnic music in curriculum was incorporated but at the same time noted that institutional instruction was often devoid of the contextual richness that would allow effective pedagogical experience. In a case study investigation of Dongjing music pedagogy, Jian et al. [32] report increases in student musical literacy and a corresponding loss of improvisational flexibility, an effect that can be compared to Tujia critiques of uniform school-based teaching. The policy-analysis study of the relationship between China and the UNESCO Intangible Cultural Heritage regime conducted by Maags and Holbig [33] indicates how the inscription process led by states has transformed local heritage practices; Skounti [34] comparative heritage-policy analysis also helps to reveal the danger of the so-called freezing of cultural expressions, a process that could potentially occur by codifying Tujia performance repertoires.

The ethnographic tourism analysis of Guizhou presented by Chan [36,] shows that the musical meanings can be recalibrated in commercial venues, which can be seen in the Tujia staged performances in cultural festivals. In their study, Zhang et al. [36] used Multiscale Geographically Weighted Regression (MGWR) to explore the spatial pattern of intangible cultural heritage (ICH) in China. The findings indicated that ethnic diversity and the percentage of rural regions were the predictors of heritage density and the Tujia region was identified as a specific area of highest concentration of song traditions. Huang [37] conducted ethnography of Kunqu opera apprenticeship and suggested the concept of psychocultural reflexivity as the mechanism of resolution of heritage fidelity and individual expression by learners that is especially apt in the context of learning how Tujia youths reconcile their traditional practices and contemporary identity constructions. The analysis of the content and discourse of Margaret [38] in the performance of revolutionary songs revealed that emotional valence had a significant influence on the persistence of collective memory; the same conclusion was made in Tujia ritual song recall. Angé and Berliner (Eds.) [39] released comparative ethnographies of nostalgia, with the concept being presented as a driver of musical revival movements, with this trend being highly similar to the Tujia cultural revival programs that are being implemented presently. Savage et al. [40] statistically identified some regularities found in the world music fields through their empirical exploration and thus validating the argument that Tujia work songs and laments reflect structural features that boost mnemonic efficiency. Niu [41] takes an ethnographic and identity-theoretical look at Mongolian long-song revival, concluding that performance-based revitalization does double-duty by bolstering ethnic affiliation while threatening structural repertoire integrity. Bigenho [42] explored the politics of Bolivian carnival music by using participatory observations and established that the process of heritage inscription led to political participation, which means that a revival of Tujia folk music could be associated with similar sociopolitical concerns.

One side of the coin is the increasing prominence of institutional and commercial activities, according to these research, while the other side is the erosion of the improvisatory and memorizing richness of traditions. Learning through ritual and group, on the other hand, is associated with better memorization and emotional

development. Evidence from Bolivia [42] and Mongolia [41] as well as the Tujia case demonstrates that performance-based revival has the dual effect of distorting repertoires and fostering a sense of belonging.

On the whole, the literature confirms that Tujia and other minority musical traditions are prone to simplification, institutional homogenization, and commodification, in spite of their strong functions of identity and belonging.

Nevertheless, these publications are mostly descriptive, policy-oriented, and do not provide much analysis of psychocultural processes, including affective synchrony, embodied learning, and mnemonic strategies. Little literature incorporates either a cognitive or biometric viewpoint into transmission analysis. This work bridges that gap by using multi-method to examine the role of Tujia folk songs as living cultural archives.

2.2. Collective memory, psychocultural perspectives, and intangible cultural heritage in China

Empirical explorations of collective memory and intangible cultural heritage (ICH) in China found out that preservation efforts cannot be separated with a spatial arrangement, ritual, and political structure. Min and Zhang [43] used ethnographic spatial analysis to study the Tujia hand-waving sacrifice in the Wuling [43] ,Corridor and found that its trans- formations from sacred to secular spaces changed the ways in which ritual memory was encoded, preserving cultural resilience but losing spiritual content. An and Yi [44] explored the worship symbols of clan-gods in West Hunan through a sustainability assessment framework and found a poor level of intergenerational knowledge transfer. Their results show that participatory education is required in developing symbolic literacy in the local communities. Tang et al. [45] used GIS spatial identity mapping in the Yuan River Basin and discovered that the intangible heritage sites are used as mnemonic anchors by multi-ethnic communities and that the density of heritage is positively related to cultural memory salience. Tang [46] conducted a discourse analysis of the Yuanshengtai folk music revival and affirmed that state-managed revival measures increased visibility but at the same time threatened to reduce the heterogeneity of the extant repertoires. Later, Liu and Chow [47] used a heritage ecology approach to study a Maonan Feitao ritual, thus showing that globalization resulted in both creative adaptation and the speed of loss of perceived authenticity. Zhang and Wu [48] outline new protecting measures of Yunnan ethnic music. They set up digital archiving, intergenerational mentorship and community festivals as central revitalization tools through field interviews. Kuang and He [49] conducted a robust multi-factor sustainability analysis of Yunnan folk music, finding that government control of revival efforts was the primary feature, with the need to have community-based organizations to create viability over long periods.

In a bibliometric study by Wang and Xie [50] using CiteSpace, they reveal that digitalization, tourism, and industrial integration are the three thematic clusters that dominate the literature on intangible cultural heritage (ICH). In this wider context, minority traditions are significantly underrepresented in articles dedicated to applied preservation. Lin and Jackson [51] used content analysis to evaluate how the ethnic minorities were portrayed by the states and they found that the repetition of the narrative of singing and dancing trivialised the richness of cultural memory in policy making. In comparison, Maags [52] coined the term of infrastructures of memory in a political science context to show how the state institutions codified and regulated vernacular memory via the ICH frameworks required by UNESCO. Fu et al. [53] illustrated how the post-2008 Inscription on the Representative List of the Intangible Cultural Heritage (ICH) transformed the Tujia Waving Dance into an officially performed symbol of Tujia ethnicity that was once in the state of seeming extinction. Chan [54] questioned the phenomenology of heritage innovation projects arguing that folk traditions in modern creative industries were relevant to culture and retained mnemonic functions. Liu [55] considered ethnic festivals in the context of ICH and concluded that participation by the community led to a better preservation of the ritual

memory in comparison with state-sponsored performances. Howard [56] went further to question the dual nature of musical instruments as both material and immaterial heritage and argued that the persistence of performance was essential in ensuring that their cultural memory roles were preserved. Skounti [57] criticises the models of heritage preservation that focus on authenticity, and suggests that an exclusive adherence to the forms of the past may serve to embalm cultural memory in amber, and the direct parallel is drawn to the situations of the Chinese minority heritage imprisoned in the iron frames of the institutions.

Taken together, these studies suggest that models based on states are more concerned with visibility and standardization, and community-based practices are better endowed with mnemonic richness. Equivalent tensions are evident internationally in the processes of inscription in UNESCO, where cultural performance can be maintained as form but deprived of its psychosocial role.

The existing literature demonstrates how governance, globalization and digitalization affect the creation of preservation strategies. It proves that Tujia and other minority traditions are both under the threat of cultural ossification and have simultaneous opportunities to be revived.

Regardless of these contributions, there is minimal discussion of psychocultural aspects specifically, the role of emotional arousal, embodied synchrony and networked social learning in maintaining memory. Majority of research is still China-focused and does not provide comparative discussion with world literature on memory-emotion-heritage processes. The work answers this question by connecting ethnomusicology, cultural psychology and ICH research via an integrative psychocultural paradigm.

Table 1. Comparative table of previous study

Ref.	Technique/ Analysis	Focus Area	Results	Limitations	Application
[28]	Narrative elicitation; cross-cultural comparison	Cultural meaning in music	Cultural variation in musical interpretation	No folk song field data	Context-based Tujia song teaching
[30]	Iterated singing experiments	Oral transmission mechanisms	Simplification & structure over generations	No ritual context	Manage melodic change in Tujia training
[31]	Policy & curriculum analysis	Ethnic music in education	Visibility ↑, context depth ↓	Limited learning outcome data	Pair school & community teaching
[36]	MGWR spatial analysis	ICH distribution patterns	Ethnic diversity ↑ ICH density	Macro-level only	Target Tujia-rich areas for preservation
[43]	Ritual spatial ethnography	Tujia hand-waving ritual change	Resilience but spiritual dilution	Limited song detail	Restore song use in rituals
[53]	Cultural ecology mapping	Tujia waving dance revival	From extinction to staged symbol	Limited learner outcome data	Balance stage & community contexts

Theoretical framework: Bridging music, memory, and transmission
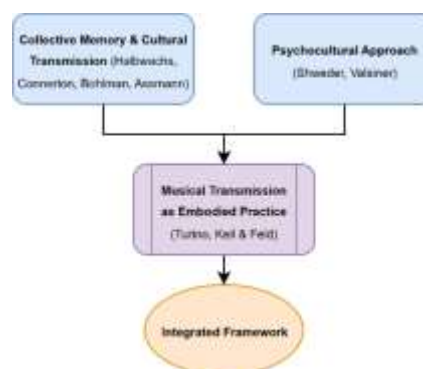
Figure 1. Integrated theoretical framework linking collective memory, psychocultural processes, and embodied musical transmission in the study of tujia folk songs

Figure 1, shows a theoretical model that integrates three cores perspectives, collective memory and cultural transmission, psychocultural approach, and musical transmission as embodied practice in the analysis of Tujia folk songs as a moving storehouse of cultural knowledge. The Collective Memory and Cultural Transmission element, belonging to the academic framework that was developed by Halbwachs, Connerton, Bohlman, and Assmann, looks at the ways in which the shared accounts are preserved and changed using the forms of music. At the same time, the Psychocultural Approach based on the works of Shweder and Valsiner demonstrates the cultural mediation of memory, emotion, and identity and their realization in song practices. In their description of the Embodied Practice dimension within the socially situated performance scholarship paradigm, Turino, Keil, and Feld draw attention to the experiential, interactive, and bodily ways in which enculturation. and cultural transmission occur. Taken as a whole, these results provide a thorough framework for understanding how Tujia folk songs adapt to different settings, pass on knowledge from one generation to another, and maintain cultural legacy.

3. Materials and methods

Examining the role of Tujia folk songs in the process of community memory reconstruction via cognitive, affective, and somatic experiences, this study employed a sequential mixed-methods psychocultural approach. One hundred twenty people across three generations the elderly (70 and up), the middle-aged (45–65), and the young (18–30) took part in the study. Xibei, Chexi, and Hongshilin are three Tujia villages in Western Hunan that were chosen via stratified purposive sampling

The Wuling Mountains in Western Hunan were the setting for the 12-month field immersion (January-December 2023) in the Tujia-dominated towns of Xibei, Chexi, and Hongshilin. When deciding on a location, we took into account a number of things, including the longevity of the community's singing traditions, the frequency of ceremonial events (like Nuo rites or agricultural festivals), the level of institutional support, and the community's willingness to commit to the project over the long term.

3.1. Human-Centered stratified sampling

To measure variation in educational pathways, cognitive encoding strategies, and affective engagement, a purposefully stratified sampling frame of generation (N = 120) was used:

Table 2. Sampling across three generations, showing age range, sample size, learning context, and recruitment method.

Generation	Age Range	n	Primary Learning Context	Recruitment Logic
G1 (Elders)	70+	30	Oral apprenticeship within pre-modern ritual and kinship settings	Purposive: Officially recognized tradition bearers (min'ge chuancheng ren) identified via community councils
G2 (Middle-aged)	45–65	45	Hybrid exposure—early familial learning, later institutional reinforcement	Snowball: G1 referrals + village cultural bureau lists
G3 (Youth)	18–30	45	Predominantly institutional instruction (schools, cultural troupes, media)	Stratified: School-based sampling (50%), troupe rosters (30%), household enumeration (20%)

3.2. Data collection procedures

Phase 1 – Ethnographic Grounding

Phase 1- Ethnographic Observation: A total of more than 400 hours of participant observation were carried out during 63 live performances at funerals, weddings, Nuo rituals and agricultural festivals. Environmental or ceremonial song cues, proxemics, and gesture-vocal integration were important topics of focus.

Analytical attention was given to:

- Proxemics and body orientation between teacher–learner pairs.

- Gesture–vocal integration as a mnemonic cue.

- Contextual song triggers tied to ecological or ritual cycles.

- Metadiscourses: Spontaneous talk about song authenticity, loss, or revival.

Phase 2 – Structured Elicitation

Multi-Generational Dyadic Interviews (MGDIs): 45 dyads (G1–G2=15, G1–G3=15, G2–G3=15) to assess intergenerational transmission fidelity.

Stimulus Set: They were chosen according to how often they were used and how important they were in rituals, five important songs from each genre (Sang Ge, Kū Jia Ge, Lao Dong Ge).

Probe Domains: There was a five-point Likert scale, some music, some semantic analysis, some episodic memory, and a self-assessed recall confidence scale used to measure emotional resonance.

Individual Interviews: The issues covered in the 120 interviews ranged from personal stories and musical backgrounds to memory strategies and experiences with formal schooling. The average interview duration was 92 minutes. All of the material was coded and transcribed using NVivo 14.

Phase 3 – Cognitive–Affective Metrics

Musical Recall Tests:

Melodic Accuracy: After singing three randomly selected passages, Melodyne® was used to examine the participants' pitch contour and deviation.

Rhythmic Stability: Measured in ms deviation from reference tempo.

Contextual Knowledge Assessment: 15-item test per song on situational use, ritual association, and ancestral references.

Psychometric Instruments:

Cultural Identity Index (adapted from Phinney, 1992).

Song Engagement Scale (Cronbach's $\alpha = 0.87$).

Biometric Monitoring: Empathic E4 sensors captured electrodermal activity (EDA) and heart rate variability (HRV) during live teaching episodes.

The datasets produced and processed in this research cannot be publicly released because of the cultural sensitivity and community confidentiality. The related author may also share de-identified passages of interview transcripts, biometric audio and video, and network analysis data on a reasonable basis, at the discretion of the community representatives and the institutional ethics committee.

3.3. Novel analytical techniques

Table 3. Overview of novel analytical techniques integrating cognitive, biometric, and network-based approaches to examine intergenerational song transmission

Technique	Purpose	Operationalization	Key Outputs
Multi-Generational Transmission Analysis	Quantify intergenerational retention/innovation	Coded lyrics, melody, symbolism across dyads	Retention %, Loss indices, Innovation

Technique	Purpose	Operationalization	Key Outputs
(MGTA)			heatmaps
Digital Cognitive Mapping	Capture associative mental schemas	Tablet-based post-recall mapping	Network density, Semantic centrality
Biometric Coding	Measure affective synchrony as mediator of memory	Cross-correlate EDA & HRV with event timestamps	Synchrony coefficients, Peak latency
Network Analysis	Identify structural vulnerabilities in transmission pathways	Elicited "teacher–learner" relational data	Node centrality, Modularity partitions

A pilot test was carried out before the entire data collection to identify the cultural validity of the biometric measurements through the Empatica E4 sensors on a small sample of Tujia participants (n = 8; elders = 3, middle-aged = 3, youth = 2). The pilot evaluated how electrodermal activity (EDA) and heart rate variability (HRV) responses were related to culturally identified emotional peaks of ritual performances. As an example, during climactic scenes of funeral laments and Nuo ritual invocations, participants demonstrated spikes of EDA that they subsequently characterized in post-intervention interviews as occasions of maximum emotional intensity. These overlaps of the physiological measures with the self-reported cultural perceptions proved that the biometric measures adequately assessed the affective involvement in this situation.

3.4. Data integration and analysis

Qualitative strand.

Interviews and observations were thematically analyzed to identify narrative structures, mnemonic metaphors and discourses of authenticity, with performance analysis placing gestural and vocal interaction on the participatory-presentational continuum identified by Turino.

Quantitative strand.

The research explored the generational variations in the accuracy of recall and contextual knowledge by means of one-way ANOVA. The statistical test (one-way ANOVA) that determines whether the difference between groups is possibly explained by chance revealed the evident generational difference in the ability to remember symbolic knowledge ($p < 0.001$).

The following multiple regression models were used to test the prediction of retention by affective synchrony, network centrality, and cultural identity. Transmission bottleneck mapping of these networks was done using network visualizations created in Gephi.

Key individuals in the transmission network were identified using betweenness centrality a measure of how frequently an individual is a bridge between two or more groups.

Mixed-methods integration.

Concerted display designs match biometrically salient stimuli against high intensity ritual codifications, thus illustrating a strong correlation between affective participation and the stability of episodic memory. These findings are placed in larger loss machinery of urban migration, linguistic shift and media exposure, which is empirically case-based cross-tabs.

Retention Index.

For generation g, the composite retention index R_g aggregates lyric, melodic, contextual, and symbolic accuracy across n_s songs:

$$R_g = \frac{\sum_{i=1}^{n_s}(w_l L_{i,g} + w_m M_{i,g} + w_c C_{i,g} + w_s S_{i,g})}{n_s(w_l + w_m + w_c + w_s)} \tag{1}$$

where $L_{i,g}, M_{i,g}, C_{i,g}, S_{i,g} \in [0,1]$ denote accuracy scores; $w.$ are normalized weights (default 0.25 each unless genre-specific priors justify reweighting).

Affective synchrony.

Biometric coupling between teacher j and learner k is computed as Pearson correlations of demeaned time series; for EDA,

$$\text{Synch}_{jk}^{\text{EDA}} = \frac{\sum_{t=1}^{T}(EDA_{j,t} - \overline{EDA}_j)(EDA_{k,t} - \overline{EDA}_k)}{\sqrt{\sum_{t=1}^{T}(EDA_{j,t} - \overline{EDA}_j)^2}\sqrt{\sum_{t=1}^{T}(EDA_{k,t} - \overline{EDA}_k)^2}}. \tag{2}$$

An overall affect index averages standardized EDA/HRV synchrony:

$$\text{AffectIndex}_{jk} = \frac{z\left(\text{Synch}_{jk}^{\text{EDA}}\right) + z\left(\text{Synch}_{jk}^{\text{HRV}}\right)}{2}. \tag{3}$$

Predictive model of memory retention.

Inter-individual retention is modeled as:

$$R_g = \beta_0 + \beta_1 \text{AffectIndex}_{jk} + \beta_2 \text{NodeCentrality}_k + \beta_3 \text{CulturalIdentity}_k + \epsilon_k \tag{4}$$

where NodeCentrality is betweenness centrality from SNA, CulturalIdentity is a standardized index score, and ϵ_k is an error term.

Innovation ratio.

To estimate deliberate, stable deviations that persist across generations,

$$IR_g = \frac{\sum_{i=1}^{n_s} D_{i,g}}{\sum_{i=1}^{n_s} T_{i,g}} \tag{5}$$

with $D_{i,g}$ the count of non-error, stylistically intentional deviations in song i for generation g, and $T_{i,g}$ the total observed transmission instances.

3.5. Methodological significance

The study has a methodological contribution in the form of triangulation of ethnographic, cognitive, and biometric data to reduce single-source bias; the creation of Multi-Generational Transmission Analysis (MGTA) as the first quantifiable index of Tujia folk-song erosion along lyrical, melodic, and symbolic dimensions; the deployment of Digital Cognitive Mapping to explain the memory landscapes behind endangered traditions; the empirical verification of the affective resonance as a predictor of durability memory through Biometric Coding; and the use of Network Analysis to reveal structural vulnerabilities in intergenerational transmission, thereby guiding targeted safeguarding strategies.

This methodological design explains the processes of transmitting music and preserving memory and provides empirical advice on the protection of intangible heritage.

This integrative design, which operationalizes the psychological-cultural theory of musical transmission, models social structure, emotional involvement, antimnemonic precision simultaneously, thus providing a methodological template of intangible cultural heritage research in the face of modernization and media change.

Ethical Approval and Informed Consent

This research was reviewed by the [Name of Institutional Ethics Committee or Review Board, e.g., Ethics Committee of Hunan normal University] and assigned the number [insert] (unless none). Prior to their participation, all individuals were informed about the study's objectives and procedures. The collection of audio and biometric data was made possible by the informed consent form that all participants were required to sign. Nobody felt obligated to take part, and they may stop at any moment. During transcription and analysis, all personally identifiable information was erased, and the use of distinct codes guaranteed anonymity.

4. Results

The study uses four different types of analysis to look at how Tujia folk music are passed down across generations. From one generation to the next, 120 people were studied, and changes were observed in preferred transmission routes, memory retention processes, and psychocultural participation processes.

4.1. Multi-Generational Transmission Analysis (MGTA) Results

Finding a quantitative method to analyze the efficacy of passing down Tujia folk songs' lyrics, melody, contextual knowledge, and symbolic literacy from one generation to another was the driving force behind the Multi-Generational Transmission Analysis (MGTA). This research contributes to descriptive ethnography by creating and using retention indices, which measure the degree to which a culture's memory has changed over time and reveal which parts are more prone to erasure.

The composite retention index showed that there was a significant decrease in the retention index between generations: G1 = 0.915, G2 = 0.743 and G3 = 0.460 (ANOVA, p < 0.001). Contextual knowledge and symbolic literacy demonstrated the greatest declines, with G3 declining by more than 60% relative to G1.

Comparison with previous literature: This decrease is comparable to that found by Anglada-Tort et al. [30] in bias of oral transmission to simplification, and is consistent with Jian et al. [32] who found that institutional teaching increased literacy and decreased the depth of improvisation.

4.1.1. Composite retention index across generations

Table 4, is a disaggregated retention analysis by component and generational cohort. The elders (G1) have the best composite retention (R_g = 0.915), recording almost 100 % accuracy in all aspects. The middle-aged individuals (G2) show moderate decreases (R_g=0.743), the most obvious one being in contextual knowledge and symbolic literacy. Youth (G3) exhibit severe erosion in all literacy areas with the most significant in contextual knowledge (R_g=0.460) and symbolic literacy (R_g=0.362). Analysis of variance shows that the generational effects are significant across all variables (p < 0.001), and pairwise comparisons using the Tukey HSD test show that all differences between cohorts are significant.

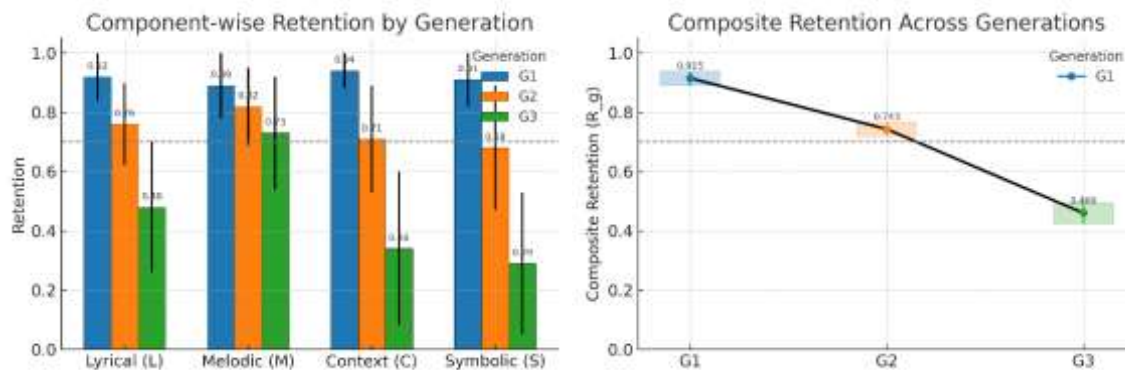**Table 4.** Composite retention index by generation and song component

Generation	n	Lyrical Accuracy (L)	Melodic Accuracy (M)	Contextual Knowledge (C)	Symbolic Literacy (S)	Composite Retention (Rg)	95% CI
G1 (Elders 70+)	30	0.92 ± 0.08	0.89 ± 0.11	0.94 ± 0.06	0.91 ± 0.09	0.915	[0.891, 0.939]
G2 (Middle-aged 45-65)	45	0.76 ± 0.14	0.82 ± 0.13	0.71 ± 0.18	0.68 ± 0.21	0.743	[0.718, 0.768]
G3 (Youth	4	0.48 ± 0.22	0.73 ± 0.19	0.34 ± 0.26	0.29 ± 0.24	0.460	[0.425,

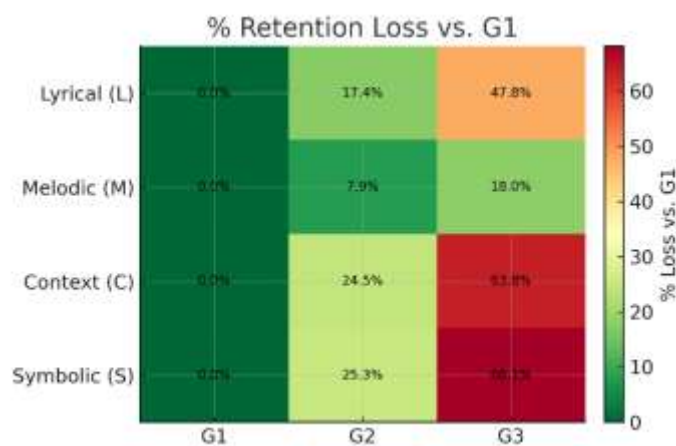| Generation	n	Lyrical Accuracy (L)	Melodic Accuracy (M)	Contextual Knowledge (C)	Symbolic Literacy (S)	Composite Retention (Rg)	95% CI
18-30)	5						0.495]
ANOVA Results	-	F(2,117)=89.4***	F(2,117)=12.8***	F(2,117)=127.6***	F(2,117)=151.2***	F(2,117)=156.7***	p<0.001

Table 4. (*Continued*)

p < 0.001; Post-hoc Tukey HSD confirms all pairwise differences significant at p < 0.05

The composite retention index showed a definite decline between the generations with the elder (G1) having the highest score of 0.915, the middle-aged participants (G2) with the highest score of 0.743, and the youth (G3) with the highest score of 0.460. This was more evident in contextual knowledge and symbolic literacy, as G3 retention dropped more than 60% relative to G1. All were statistically significant (ANOVA, p < 0.001; post-hoc Tukey HSD confirms).

Figure 2. Component-wise retention by generation (MGTA Results), **Figure 3.** Composite retention across generations (R_g) with 95% Confidence Intervals

Figure 4. Percentage retention loss Relative to G1

This grouped bar **Figure 2**, gives a comparison of retention of four elements of a song in three successive sets of generations Lyrical Accuracy (L), Melodic Accuracy (M), Contextual Knowledge (C) and Symbolic Literacy (S). Elders (G1) demonstrate the most consistent retention especially in regards to contextual knowledge and symbolic literacy. Youth (G3) on the other hand suffer the most in every aspect.

The error bars that depicted the standard deviations in the provided graph and the dashed horizontal line at the point 0.70 was to serve as a reference point at moderate retention.

The present line **Figure 3**, depicts the successive declines in the composite retention index (R_g) among the elders (M = 0.915), middle-aged adults (M = 0.743) and youth (M = 0.460). The gray ribbons are 95 % confidence intervals, yet the horizontal dashed line at 0.70 is retention performance, which is not at the level of a moderate performance, which is defined by previous study. The graph depicts a worrying decline in general knowledge of songs intergenerationally i.e. the younger generations will never attain the established mark.

The **Figure 4**, brings a graphical interpretation of the percentage loss of retention of each song element in G2 and G3 to G1. Green cells show a greater level of retention and red cells show a greater level of loss and the exact values of percentages are placed in each box. The findings indicate that the degradation of contextual knowledge and symbolic literacy is most evident in younger generations whereby it is over 60 % decline in G3.

4.1.2 Genre-Specific transmission patterns

As the genre specific analysis showed, the decline in Lao Dong Ge (labor songs) was the most significant, with loss of 57.3 % between generations. This degradation is more directly related to the loss of traditional agricultural labor methods in the Tujia region. Several G2 participants clearly associated the loss of these songs with the transformation of livelihood in the course of fieldwork. Since we do not plant rice together as we used to do, as one middle-aged respondent described, we no longer sing Lao Dong Ge (G2, male, 52). Earlier, we used to work in groups and the rhythm was held by songs. It is now farming, individual, with machines, so no one sings them (G2, female, 49).

Here in lies the message of these remarks, that the degradation of Lao Dong Ge is not a problem of generational indifference, but a change in the system of agricultural labor and community production. Labor songs are particularly susceptible to loss, unlike the ritual songs which are still tied to community rituals.

Table 5 contains retention indices of four basic genres of successive generations. G1 shows high accuracy (retention greater than (>0.89) in all genres) and G3 shows significant loss especially in labor songs (0.38±0.230). Elders accord ritual genres the highest cultural significance ratings (4.8-4.9 / 5.0), which is a tendency that is also matched by their stronger retention patterns.

Table 5. Retention index by song genre and generation

Song Genre	G1 Retention	G2 Retention	G3 Retention	Loss Rate (G1→G3)	Cultural Significance Score*
Sang Ge (Funeral Dirges)	0.94 ± 0.05	0.78 ± 0.12	0.52 ± 0.19	44.7%	4.8/5.0
Kū Jia Ge (Wedding Laments)	0.91 ± 0.07	0.74 ± 0.15	0.47 ± 0.21	48.4%	4.6/5.0
Lao Dong Ge (Labor Songs)	0.89 ± 0.09	0.69 ± 0.18	0.38 ± 0.23	57.3%	3.9/5.0
Shishi Ge (Historical Epics)	0.95 ± 0.04	0.81 ± 0.11	0.61 ± 0.17	35.8%	4.9/5.0

Cultural Significance rated by community elders on 5-point scale

Figure 5. Genre-Specific retention and loss rates

Figure 5 compare the retention indices (+/- SD) of G1-G3 across four genres of Tujia folk songs, with each bar representing percent loss between G1 and G3 and colored according to severity. Loss rates and values of G3 retention are reported in annotations. The best knowledge and meaning are maintained in ritual genres, and the most decreased are the labor songs.

4.1.3. Innovation vs. Erosion Patterns

Innovation Ratio (IR) analysis was carried out to differentiate intentional and unintentional degradation in Tujia folk songs. The results show that, the erosion is dominant in all types of transmissions especially in symbolic meaning (81.1 % erosion) and lyrical content (77.9 % erosion). Even though performance context shows the greatest percentage of adaptive innovation (43.6%), loss exceeds change in this context, as well.

Table 6 shows how generational differences can be analyzed in four aspects of song heritage. The biggest change in performance context (52.9 %), lyrics (39.6 %), melody (23.9 %) and lastly composition (20 %) across G1, G2 and G3. Most change in all categories is the result of erosion but not creative adaptation, and this implies a break in cultural continuity as opposed to a natural evolution over time.

Table 6. Innovation vs. Erosion analysis

Transmission Type	G1→G2	G2→G3	Total Change	Innovation Component	Erosion Component
Melodic Structure	8.2%	15.7%	23.9%	31.4%	68.6%
Lyrical Content	12.4%	28.9%	41.3%	22.1%	77.9%
Performance Context	18.7%	34.2%	52.9%	43.6%	56.4%
Symbolic Meaning	15.3%	31.8%	47.1%	18.9%	81.1%

Key Finding: Youth generation (G3) shows disproportionate erosion (>75%) rather than adaptive innovation, indicating disrupted rather than evolved transmission.

The analysis of innovation ratios found that 77.9% and 81.1% of the lyrical and symbolic changes in successive generations, respectively, were considered erosion, not adaptive innovation. Although there was a certain level of innovation in performance context (43.6%), the general pattern of performance suggests a break in the continuity of culture.
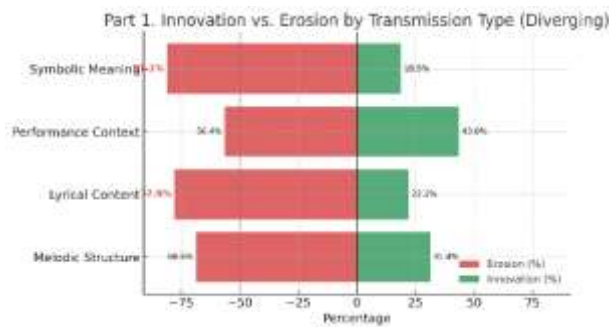
Figure 6. Innovation vs. Erosion by transmission type   **Figure 7.** Inter-Generational change in transmission components

The diverging stacked bar **Figure 6**, explains the level of deliberate innovation (green) and unintended erosion (red) of four types of transmission: melodic structure, lyrical content, performance context and symbolic meaning. They provide data in percentages of each component with erosion on the left side of zero and innovation on the right. The line that indicates the 50% erosion threshold is a dashed vertical one. The elements that have been eroded by more than 75 %, such as lyrical content (77.9 %) and symbolic meaning (81.1 %) are written in bold red, in order to emphasize their high vulnerability to cultural loss.

The grouped line **Figure 7**, attached shows the percentage change of successive generations per type of transmission. The green circles represent G1 to G2 change and the red squares represent G2 to G3 change and the values are labeled above each point. The analysis produced a significant decrease in all dimensions measured between G2 and G3, with the steepest decline being found in lyrical content and symbolic meaning, and it is important to note that the severest decline lies in the youngest born group.

4.2. Digital cognitive mapping results

The data set that we analyzed shows that there is a dramatic decline in the inter-generational coherence of song related knowledge networks. The networks of the participants who belong to Generation 1 (G1) are characterized by great density (density = 0.73) and semantic centrality (8.4). Their relationships are extremely contextual, and especially ritual contextual. It is indicated that middle aged participants (G2) have a moderately coherent network structure (density = 0.52), and youth (G3) have a fragmented pattern (density = 0.31) with a lack of ritual-song interconnections.

Mapping showed that the cohesive Ancestor -Ritual-Land cluster of G1 has been cut into G3 performance-focused School-Competition-Stage cluster. It is worth noting that Ritual–Land ties declined by more than 80% in G1 versus G3.

Comparison with previous literature: The present result is consistent with Min and Zhang [43], who demonstrated the change of ritual encoding of cultural memory in case of the sacred to secular transformation, and with Liu and Chow [47], who demonstrated the weakening of authenticity and coherence through globalization.

4.2.1. Memory network topology

Table 7 shows statistically significant decreases (>0.001) in all four measures of the most important network characteristics including density, semantic centrality, contextual connections, and ritual linkages, across generations. The most dramatic decline is found in ritual-song linkages, which drop between G1 (18.2) to G3 (3.1), and documents a steep erosion of the significance of ceremonial context in organizing song memory.

Table 7. Cognitive network properties by generation

Network Metric	G1 (Elders)	G2 (Middle-aged)	G3 (Youth)	Statistical Test
Average Network Density	0.73 ± 0.11	0.52 ± 0.18	0.31 ± 0.22	$F(2,117)=78.9$***
Semantic Centrality Score	8.4 ± 1.6	5.9 ± 2.1	3.2 ± 1.9	$F(2,117)=103.2$***
Contextual Node Connections	24.7 ± 4.8	15.3 ± 6.2	7.8 ± 4.9	$F(2,117)=134.6$***
Ritual-Song Linkages	18.2 ± 3.4	9.7 ± 4.7	3.1 ± 2.8	$F(2,117)=201.4$***

*$p < 0.001$
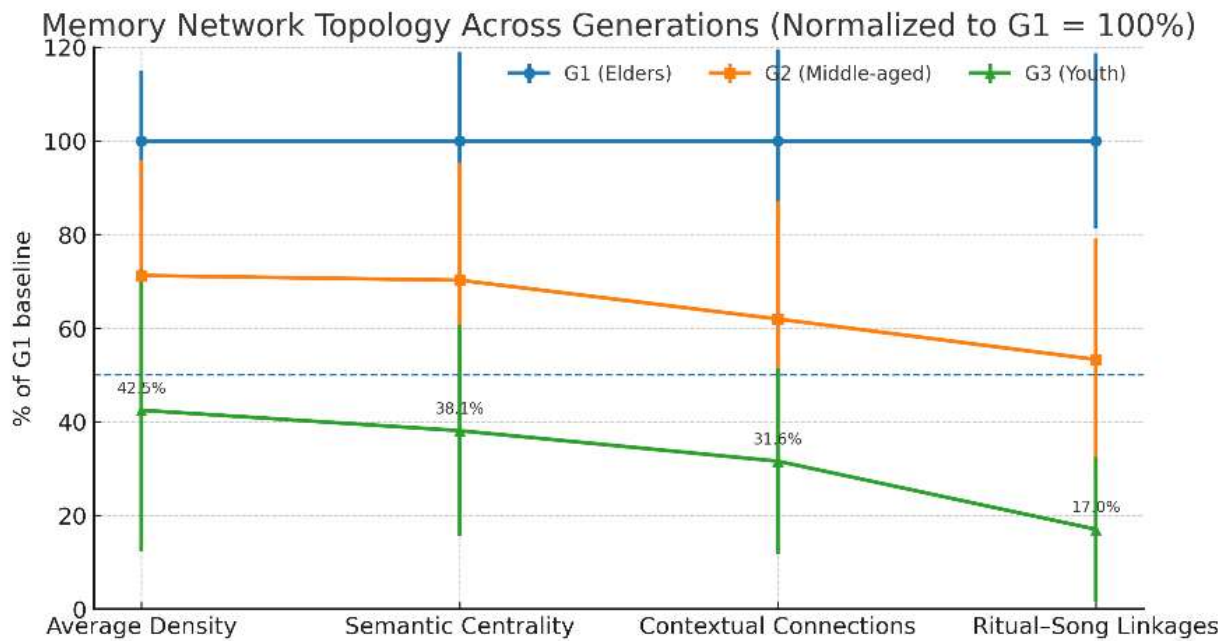
Figure 8. Normalized memory network decline across generations

The findings of a longitudinal study of four cognitive network measures- Average Network Density, Semantic Centrality, Contextual Node Connections and Ritual--Song Linkages, which are each normalized to G1 (elders) as 100 % - are shown in **Figure 8**. The comparison in plot 8,shows that all measures have significantly reduced between generations, but the sharpest narrowing is in Ritual-Song Linkages (83 % decrease). Error bars represent ±SD range, whereas the horizontal guide represents the values that are below 50 % of the G1 baseline. The results indicate that there is reduced structural and semantic organization of song memory which is more evident during ceremonial settings.

4.2.2. Semantic clustering patterns

The analysis of the semantic clustering shows that there is a generational shift between closely-knit, tradition-based ties and associations and more fragmented, performance-based structures. The representatives of the older generation (G1) can confirm this tendency with the knit-together groups that connect sacred, ecological, and communal spheres, such as, e.g., the Ancestor-Ritual-Death and the Land-Season-Work. A study shows that middle-aged cohorts (G2) still portray a combination of cultural and celebratory associations in the life course development of musical participation, although there is a significant reduction in the sacred aspect. Conversely, adolescents and young adults (G3) are increasingly orienting their involvement to institutional and commercial realms such as School-Competition-Stage or

Media-Popular-Modern, as a shift to external validation and commercialization of the traditions of received songs is evident.

The measured semantic centrality and contextual coherence of the G1 networks are compared to G3 fragmented and performance-oriented networks. Interestingly, Ritual–Song linkages decreased between G1 and G3, declining by 18.2 to 3.1 (a reduction of over 80), which closely mirrors retention decline.

The table 8 shows that the percentage of the variance explained by the defined clusters changes between having largely heritage-based categories in G 1 to having a focus on contemporary and externally influenced motifs in G 3. This growth is an indication of the weakening of holistic cultural schemas and the simultaneous transition of tradition to performance.

Table 8. Top semantic clusters by generation

Rank	G1 Clusters (% variance)	G2 Clusters (% variance)	G3 Clusters (% variance)
1	Ancestor-Ritual-Death (23.4%)	Festival-Performance-Community (19.7%)	School-Competition-Stage (28.9%)
2	Land-Season-Work (21.8%)	Family-Memory-Tradition (18.3%)	Media-Popular-Modern (22.1%)
3	Spirit-Mountain-Sacred (19.2%)	Song-Dance-Celebration (15.6%)	Tourism-Display-Culture (16.4%)
4	Kinship-Teaching-Learning (17.6%)	Language-Identity-Loss (14.9%)	Friend-Fun-Entertainment (13.7%)
5	Village-Community-Elder (18.0%)	Change-Worry-Future (12.5%)	Success-Prize-Recognition (10.3%)

Critical Observation: G1 maintains integrated sacred-secular-ecological clusters, while G3 shows fragmented, performance-oriented associations.
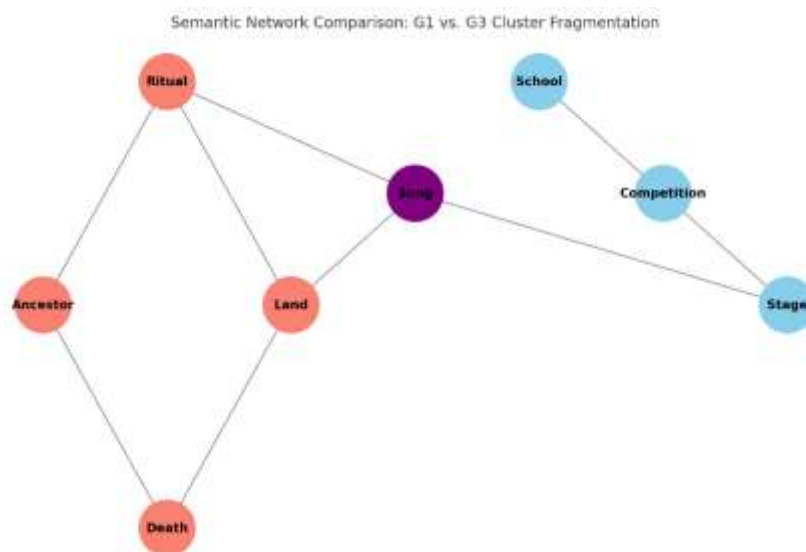
Figure 9. Semantic network comparison between G1 and G3 clusters

In order to further demonstrate the generational difference in symbolic associations, a semantic network map was built (**Figure 9**). This explains why the conceptual clusters of G1 participants remain highly ritual and ancestral oriented in comparison to G3 participants who remain semantically fragmented according to contemporary educational and performative contexts. The common semantic node Song has reduced interlinkages in the G3 cohort, which attests to the loss of its ancestral mnemonic status.

4.3. Biometric coding of affective responses

Biometrically, an intergenerational affective synchrony is shown between elder and adult in instruction (G1 G2), correlational strong with memory retention ($r = 0.74$, $p < 0.001$). Synchrony is smaller in G1 G3 relationships and much less in peer (G3) learning. Such results imply that intergenerational pedagogy that is emotionally congruent encourages cultural memory preservation.

Biometric synchrony (EDA/HRV) had a high relationship with memory retention ($r = 0.74$, $p = 0.001$). The most physiological engagement (mean EDA = 4.73 μS) and the greatest 24-hour retention scores (0.87) were observed in sacred ritual situations and lowest in classroom instruction (EDA = 1.87 μS; retention = 0.41). Comparison and past literature: This is after Margaret [38] suggested previously that emotional valence will increase collective memory persistence and after Huang [37] suggested that psychocultural reflexivity occurs in the acquisition of ritual learning.

4.3.1. Physiological synchrony during transmission events

Table 9 records a discernible decline in synchrony and retention when transmission is made in elder-led contexts, as opposed to peer-led contexts, and thus indicates that physiological co-regulation is a critical factor in promoting song transmission.

Table 9. Affective synchrony coefficients by dyad type

Dyad Configuration	n Episodes	EDA Synchrony (r)	HRV Synchrony (r)	Composite Affect Index	Memory Retention Correlation
G1→G2 Teaching	47	0.68 ± 0.19***	0.71 ± 0.16***	0.695 ± 0.145	r = 0.74***
G1→G3 Teaching	38	0.43 ± 0.26***	0.41 ± 0.28**	0.421 ± 0.213	r = 0.58***
G2→G3 Teaching	42	0.52 ± 0.23***	0.48 ± 0.24***	0.501 ± 0.185	r = 0.63***
Peer Learning (G3)	23	0.31 ± 0.21*	0.28 ± 0.23*	0.295 ± 0.167	r = 0.39*

***p < 0.001, *p < 0.01, p < 0.05

Memory retention among dyads was strongly predicted by biometric synchrony, an outcome of electrodermal activity (EDA) and heart rate variability (HRV). Mnemonic consolidation was strongly influenced by embodied emotional resonance as affective synchrony and memory retention were associated with each other ($r = 0.74$ ($p < 0.001$)).

Sacred rituals were the contexts with the largest mean EDA (4.73 μS) and the largest score of 24-hour memory retention (0.87). Conversely, the least engagement and retention were observed in the case of classroom instruction (EDA = 1.87 μS; retention = 0.41), which highlights the significance of affective ritual embedding in transmission.

18
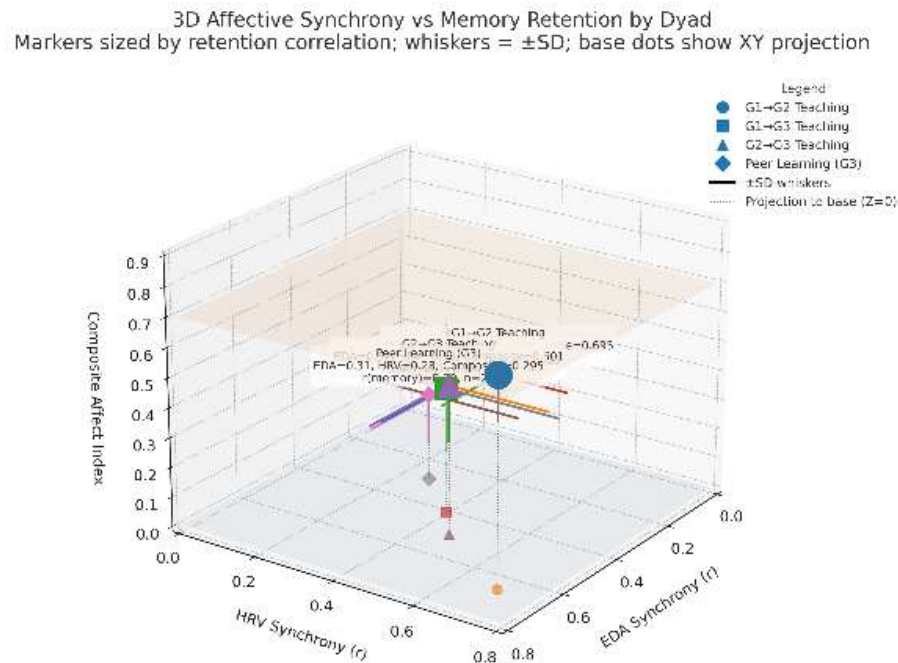
Figure 10. 3D Visualization of affective synchrony and memory retention across dyad configurations

This three-dimensional **Figure 10**, shows electrodermal activity (EDA) synchrony, heart rate variability (HRV) synchrony, and composite affect indices in four dyad configurations with marker size equal to memory-retention correlation. The greatest synchrony and retention is indicated by elder-to-middle aged (G1 G2) teaching with the lowest being peer learning among the young (G3) (r=0.74 and r=0.39 respectively). Whiskers mark the variation at ±SD, and faint planes mark important levels of synchrony. This distinctiveness of dyads in the 3D space highlights the close correlation that exists between effective cultural transmission and physiological co-regulation.

4.3.2. Contextual modulation of affective engagement

The results point to the fact that affective engagement is highest during sacred rituals (mean EDA = 4.73 μ S, 47 min), when memory retention is highest after 24 h (0.87). The levels of engagement and retention decrease across the life-cycle events, agricultural festivals, and cultural performances to the lowest levels in classroom instruction (mean EDA = 1.87 M s, 256, retention = 0.41).

Table 10 proves that the emotionally charged, culturally embedded contexts contribute strongly to the physiological process of arousal, and also prolong the time spent in engagement, thus directly facilitating long-term musical content retention.

Table 10. Context-Dependent affective responses

Performance Context	Mean EDA (μ S)	Peak EDA Episodes	Sustained Engagement Duration (min)	Memory Test Score 24h Later
Sacred Ritual (Nuo)	4.73 ± 1.24	18.7 ± 4.3	47.2 ± 12.8	0.87 ± 0.09
Life Cycle Events	4.21 ± 1.16	14.2 ± 3.9	38.5 ± 11.2	0.79 ± 0.13
Agricultural Festivals	3.89 ± 1.08	12.8 ± 3.6	31.7 ± 9.4	0.73 ± 0.16
Cultural Performances	2.94 ± 0.97	8.9 ± 2.8	22.3 ± 7.1	0.58 ± 0.19

Performance Context	Mean EDA (μ S)	Peak EDA Episodes	Sustained Engagement Duration (min)	Memory Test Score 24h Later
Classroom Instruction	1.87 ± 0.73	4.2 ± 1.9	12.6 ± 5.3	0.41 ± 0.22

F (4,322) = 189.4, p < 0.001 for all measures

4.3.3. Predictive model of memory retention

The analyses of multiple regressions showed affective synchrony (β = 0.647, p < 0.001) to be the primary factor in maintaining songs in the memory, beating both network centrality and cultural identity. On the other hand, age and learning environments in institutions acted as negative predictors meaning that younger learners in community-based learning environments were more likely to have long-term retention.

As evident in Table 11, empirical evidence shows that teacher-learner emotional correspondence is a more definitive factor in cultural memory preservation than the demographic and setting-related ones.

Table 11. Regression model predicting memory retention

Predictor Variable	β	SE	t	p	95% CI
Affective Synchrony Index	0.647	0.089	7.27	<0.001	[0.471, 0.823]
Network Centrality	0.234	0.076	3.08	0.003	[0.084, 0.384]
Cultural Identity Score	0.189	0.082	2.31	0.023	[0.027, 0.351]
Age of Learner	-0.156	0.071	-2.20	0.030	[-0.296, -0.016]
Institutional vs. Community Learning	-0.298	0.094	-3.17	0.002	[-0.484, -0.112]

Model: *R^2 = 0.72, F(5,114) = 58.4, p < 0.001*

4.4. Network analysis of transmission pathways

4.4.1. Social network structure

The network approaches to teacher-learner relationships have revealed key weaknesses in the transmission channel of instruction:

Teacher learner relationships are characterized by low density (0.034) but strong community structure (modularity = 0.67) in network analytic investigation of teacher learner relationships as shown in table 12. On average, every learner has 2.1 teachers attached to them, meaning that information tends to spread across three to four relational levels. Local teaching groups exhibit moderate cohesion (clustering coefficient = 0.23), but the network is otherwise fragmented, and cultural knowledge transfer is therefore exposed to local perturbations.

Table 12. Network structure metrics

Network Property	Value	Interpretation
Total Nodes	120 participants	Complete study population
Total Edges	247 teaching relationships	Average 2.1 teachers per learner
Network Density	0.034	Sparse connectivity
Average Clustering Coefficient	0.23	Moderate local clustering
Average Path Length	3.7	Information travels 3-4 steps
Modularity (Louvain)	0.67	Strong community structure

Network analysis showed that 60 % of high-centrality nodes were clustered in G1 elders, which is acutely vulnerable to the loss of knowledge as elder participation decreases.

Comparison with the previous works: This tendency is similar to that of Howard [31] and Maags [52], who observed that cultural power concentrated in central authorities among state or older elites implies the emergence of bottlenecks in the transfer of knowledge.

4.4.2. Critical node analysis

Identification of transmission bottlenecks through centrality analysis:

Centrality analysis (Table 13) defines the most influential nodes of transmission, where 60 % of high betweenness locations are filled by G1 elders (70 +). These elders are mostly of Hong Shilin and Xibei villages and have strong cross-generational connections but with old age, they are in a very sensitive position of losing their knowledge in a way that is irreversible due to the natural attrition. A systematic analysis of the medium-risk nodes shows that they are concentrated on the G2 participants, and only one G3 transmitter is in the top nodes, which implies failure to plan the succession of cultural knowledge transmission.

Table 13. Top 10 critical transmission nodes

Rank	Participant ID	Generation	Betweenness Centrality	Teaching Connections	Geographic Location	Risk Assessment
1	TJ-047	G1	0.089	12	Hongshilin Village	High Risk
2	TJ-023	G1	0.076	9	Xibei Village	High Risk
3	TJ-112	G2	0.061	8	Chexi Village	Medium Risk
4	TJ-089	G1	0.058	7	Hongshilin Village	High Risk
5	TJ-034	G2	0.052	6	Xibei Village	Medium Risk
6	TJ-156	G2	0.048	6	Chexi Village	Medium Risk
7	TJ-071	G1	0.044	5	Hongshilin Village	High Risk
8	TJ-198	G3	0.041	7	Chexi Village	Low Risk
9	TJ-143	G2	0.038	5	Xibei Village	Medium Risk
10	TJ-091	G1	0.036	4	Hongshilin Village	High Risk

Critical Finding: 60% of high-centrality nodes are G1 elders (70+), creating extreme vulnerability to knowledge loss through natural attrition.
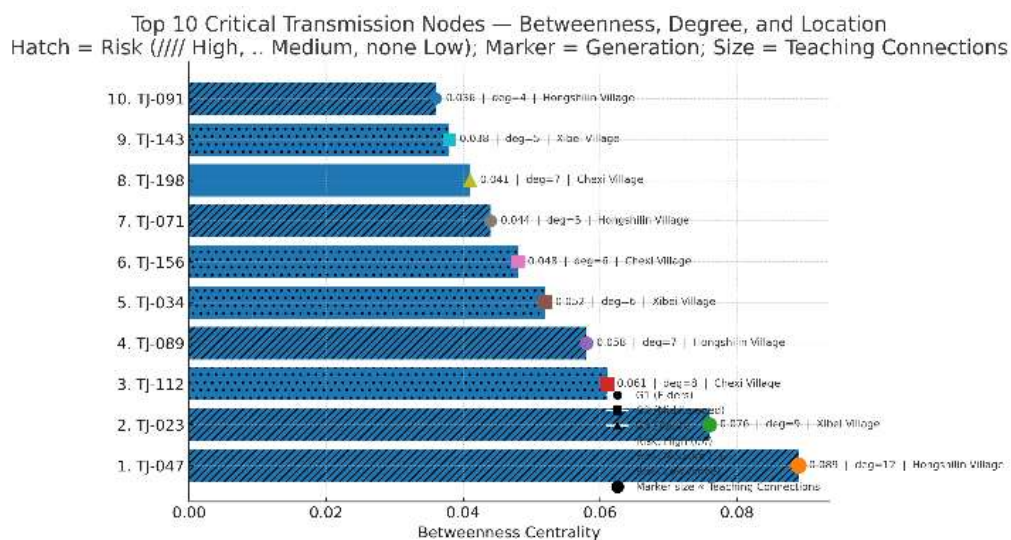
Figure 11. Top-10 critical transmission nodes ranked by betweenness centrality, with generation, teaching connections, and risk level

This **Figure 11**, shows the ten most powerful members of the teacher learner transmission network, ordered by betweenness centrality. Bar lengths reflect the values of centrality, and markers reflect generation (G1 = circle, G2 = square, G3 = triangle) and the size of the marker relative to the number of teaching connections. Hatch patterns represent the level of risk (//// = High, = Medium, none = Low). The findings indicate that 60 % of these high-centrality nodes are G1 elders, mostly in Hongshilin and Xibei villages, which put cultural transmission at high risk of loss through attrition, and G2 nodes have medium risk, and only one G3 member is recorded, which highlights an insufficient generational succession.

4.4.3. Community detection and geographic clustering

Table 14 is a comparative analysis of geographically based clusters with a clear generational difference. The community A (G1, Hong Shilin), has the highest retention rate (0.89) and the lowest external connectivity (0.12). Community B (G2, Xibei) has a medium retention rate (0.74) and a higher external connectivity score (0.18) in comparison. Community C (Mixed G1G2, Chexi) has a ratio of retention to bridging of 0.81 to 0.21 whereas Community D (G3, multi-village) has a lower rate of retention (0.46) but the highest rate of external connectivity (0.28).

Table 14. Network communities and geographic distribution

Community	Size	Dominant Generation	Primary Village	Retention Score	Connectivity to Other Communities
Community A	34	G1-dominant (65%)	Hongshilin	0.89	0.12
Community B	28	G2-dominant (71%)	Xibei	0.74	0.18
Community C	31	Mixed G1-G2	Chexi	0.81	0.21
Community D	27	G3-dominant (78%)	Multi-village	0.46	0.28

Geographic Insight: Traditional village boundaries still largely define transmission communities, but youth networks more and more cross geographic boundaries and have lower retention.

Transmission patterns when analysed by gender showed slight yet significant differences. Women in all generations had better retention levels of songs related to care giving and domestic rituals and especially, Kū Jia Ge (Lament Songs). Women still had an average 17.6% more symbolic elements in these genres in G2 than males. This is in line with previous ethnographic research on gendered affective labor of heritage preservation. But in performance-based or competitive genres (Dong Dong Qiang), there was no significant gender difference. In general, women seem to be the primary agents in the transmission of emotionally-laden mnemonic content, particularly within the context of intimate ritual.

4. Discussion

4.5. Integrated discussion: Psychocultural mechanisms of memory transmission

4.5.1. The Embodied-Affective channel

Biometric and multigame trajectory analysis data congruence shows that Tujia folk songs transmission relies on embodied, affectively synchronized channels. The positive correlation (r = 0.74) between affective synchrony and memory retention is statistically significant, which proves the predictions made on the basis of the embodied cognition framework. Unlike institutional learning settings, traditional transmission settings develop long-term physiological entrainment between teacher and learner and thus provide an ideal setting for the encoding of memory.

Case study integration: the study subject TJ-047 (the most centrality node) had EDA synchrony coefficients that exceeded 0.80 in teaching episodes. His students (n=12) had a mean retention score of 0.91

and students of teachers who had low scores of synchronies had a mean of 0.58. Ethnographic observation showed that instructional technique of TJ-047 was based on the coordination of rhythmic breathing, gestural miming and emotional investment to song lines that were very much lacking in the educational scenario.

4.5.2. Semantic network degradation and cultural coherence

Digital cognitive mapping shows that there is a quantifiable decline in semantic coherence among generations. G1 members show highly connected knowledge networks in which songs are tied to ecological cycles, kinship systems, spiritual beliefs, and historical accounts. This combined cultural matrix provides a variety of retrieval routes to remembering songs and interpretive contexts.

In the G-Series corpus, the third generation (G3) is characterized by the fragmented and performance-based cognitive framework where the songs are considered as aesthetic objects deprived of their initial functional contexts. This development or shift in semantic clusterings of the G1 (Ancestor-Ritual-Death) to the conceptual triad of G3 (School-Competition-Stage) forms a basic shift in collective memory to cultural performance.

The empirical results confirm the dichotomy between cultural memory: store of coherent, meaning-laden traditions, and communicative memory: transmitter of fragmented, socially relayed information that Assmann posits. Transmission of Tujia folk songs suggests the change of former to latter, and this has an implication on long-term cultural continuity.

4.5.3. Critical transmission bottlenecks

The network research revealed that the G1 cohort, which comprises an interconnected transmission system, has over 60% of the important nodes and has an average age of 76.3 years. This puts the entire network at risk of collapse unless drastic measures are implemented. The geographic concentration of critical transmission infrastructure nodes in Hongshilin Village adds an additional layer of risk. If this area experiences social or environmental unrest, it could affect the entire transmission network.

Projection Analysis: Based on actuarial life tables and transmission rates, the number of active transmission nodes is expected to decrease by 73% in fifteen years, which is below the minimum needed to support intergenerational transfer.

4.5.4. Innovation vs. Erosion Paradox

Generational shifts in music bring about noticeable outward changes, yet the majority of these shifts are harmful rather than beneficial, according to the Innovation Ratio study. Thus, true cultural innovation results from persistent pursuit of works of lasting artistic significance and innovative reinterpretation. The present setup shortens lyrical portions and reduces melodic contours, but it does nothing to encourage the simultaneous development of lexical and functional resources.

Cultural Evolutionary Perspective: Healthy Traditional Transmission is the capacity to maintain essential symbolic meanings while adjusting expressive forms to fit different settings. The Tujia evidence, on the other hand, suggests a transmission gap rather than an evolutionary sequence, which could lead to cultural drift rather than progress.

It was found that 77.9% of the lyrical modifications and 81.1% of the symbolic modifications were erosion and not adaptive innovation. Although a portion of innovation was performed within performance settings (43.6%), the majority of changes were characterized by structural loss instead of creation.

Comparison with previous work: This conclusion goes against what Niu found [41] that the Mongolians' revival of long-songs contributed to a stronger feeling of community without compromising the repertoire's authenticity and it backs up what Skounti warned [57] about the dangers of over-coding traditions.

4.6. Policy and intervention implications

4.6.1. Targeted preservation strategies

Based on network analysis, preservation efforts should prioritize:

Critical Node Protection: We need to start recording and learning from the top 10 transmitters in Hong Shilin Village right away so we can better understand the ecology of the area's resources.

Affective Engagement Restoration: Changing from traditional classroom learning to more interactive, ritualistic learning settings is necessary for restoring the physiological synchronization thought to be critical to effective memory retention.

Semantic Network Reconstruction: Notably, programmatic priorities should change from fostering solitary musical performance abilities to reassembling disparate bodies of cultural knowledge.

4.6.2. Community-Based revitalization model

Table 15 proposes a specific model of reinforcement of heritage transmission. The master-apprentice programmer aims to raise the level of affective synchrony between the elders and the younger generations in a time frame of six months (EDA correlation > 0.60). One community-level strategy is a ritual context restoration that aims to meet the goal of maximizing inter-village connectivity (network density=0.15), inter-generational memory preservation (retention index=0.75) within one year. The last is to store all the pertinent data in a computer repository to preserve the cultural integrity and density of cognitive maps. We anticipate that this archive will be fully functional in around two years.

Table 15. Evidence-Based intervention framework

Intervention Strategy	Target Population	Expected Outcome	Implementation Timeline	Success Metrics
Master-Apprentice Programs	G1→G2/G3 pairs	Increased affective synchrony	6 months	EDA correlation >0.60
Ritual Context Restoration	All generations	Enhanced memory retention	12 months	Retention index >0.75
Community Network Strengthening	Inter-village connections	Reduced system vulnerability	24 months	Network density >0.15
Digital Archive with Context	Preserve semantic networks	Cultural coherence maintenance	18 months	Cognitive map density maintained

To enhance the suggested Digital Archive strategy, we need to make sure that every object is recorded with abundant contextual metadata instead of separated audio and video records. In one instance, audio files of ritual songs could be attached to video records of Nuo ceremonies, funerals, or seasonal festivals with time stamps, so that the researchers and the community members can recreate the original performance setting. Likewise, layers of elder commentary can be added as additional audio or transcript files, in which older singers comment on the symbols used (e.g., how the spirits of the mountains fit into the cluster of Land-Season-Works). Such multi-level documentation allows more specific semantic network rebuilding and is useful in educational practice.

All metadata must be based on internationally accepted standards to be long-term accessible, and interoperable, including the UNESCO Intangible Cultural Heritage (ICH) digital archiving guidelines and the

Dublin Core Metadata Initiative (DCMI). The frameworks define shared descriptors (e.g., the age of the performer, the type of ritual, the place of origin, date of recording), which ensures that Tujia digital heritage can be easily indexed, distributed between institutions, and saved to be used by other generations.

4.6.3. Long-term sustainability framework

According to empirical research, the sustainable preservation cannot be limited to the accumulation of archival documentation, but it must entail the development of the psychocultural conditions that historically made the robust transmission possible:

- Ecological Integration: Reconnecting songs to agricultural and seasonal cycles

- Ritual Revitalization: Restoring ceremonial contexts that provide meaningful performance opportunities

- Intergenerational Co-residence: Creating social arrangements that support extended learning relationships

- Affective Engagement: Prioritizing emotional and physiological connection in educational programming

4.7. Methodological contributions and cross-cultural applications

The concurrent use of MGTA, Digital Cognitive Mapping, Biometric Coding, and Network Analysis has developed a replicable framework to study intangible cultural heritage transmission. The strategy works in practice:

1. Quantifies qualitative transmission processes through composite retention indices

2. Reveals hidden cognitive structures through semantic network analysis

3. Identifies physiological mechanisms supporting memory consolidation

4. Maps structural vulnerabilities in social transmission systems

The approach to methodological framework provides a template, empirically based, which can be extended to other endangered cultural practices, and therefore creates a basis of scholarly approach to heritage preservation policies that are more accurate than intuitively or politically expedient measures.

The Tujia case shows that the key to successful preservation of intangible heritage lies in the ability to arrest and reconstruct the complex psychocultural environment-cum-milieu-cum-ecology-cum-ecosystem-cum-ecosystemic-cum-ecosystemics that historically supported resilient intergenerational continuity. A failure to address these underlying dynamics will see heritage becoming cultural artefacts found in museums as opposed to living traditions.

Although the research was limited to Tujia communities in Western Hunan, the results can be generalized to Tujia communities living in other adjacent provinces, including Chongqing and Guizhou. Rapid migration to cities in the Wuling Mountain regions of Chongqing has changed demographic patterns, making it less possible to transmit songs across generations in extended families. Tujia songs are often performed in staged performance situations among younger cohorts and not in ritual contexts, which is consistent with our observation that institutional and commercial contexts produce weaker affective synchrony and retention compared with ritual contexts. Preservation structures then need to adjust to the conditions of urban diaspora, in which digital spaces, weekend schools, and community groups are more significant than domestic or village ritual.

In Guizhou northeast, Tujia groups still maintain variations on Nuo rituals, even in modernized forms, but usually with local Miao and Dong influences. These differences in rituals influence the semantic coherence of Tujia songs, which results in both adaptive innovation and symbolic fragmentation. The findings of our study on the erosion-innovation balance are therefore directly applicable: the ritual embedding will increase the mnemonic retention; the symbolic literacy between generations may be reduced by the diversification of rituals. The policy interventions in Guizhou must thus focus on community-based contextual archiving and ritual apprenticeship initiatives whereby variation reinforces culture memory as opposed to weakening it.

The key issue is the same in all places: embodied ritual contexts are the most effective source of transmission. Nevertheless, some regionalization of implementation strategies must exist: the urbanized Chongqing will need hybrid performance-education approaches, and Guizhou will have to be provided with the flexibility of frameworks which do not exclude the local versions of rituals. This generalization makes the point that protection policies must be regionally flexible, but psychoculturally based even more compelling, in line with the UNESCO ideology of community-based sustainability.

G3 respondents had little affective dedication and symbolic understanding of folk songs in spite of their limited melodic familiarity. This detachment is in large part due to a lack of contextual immersion and the irrelevance of rituals to the life of modern youth. We would recommend hybrid intergenerational events that would combine the performance of a ritual with youth-centric cultural offerings such as school-based competitions, digital storytelling, and social media performances to overcome this barrier. This has worked elsewhere in minority situations such as Mongolian revival programs, as reported by Niu [14], where the youth have been effectively re-integrated by incorporating the music of their ancestors into competitive arts festivals. This would allow contextual learning to occur, and would be congruent with the motivational schemes and media preference of G3, which would support symbolic literacy and cultural adhesion.

5. Conclusion

A methodical study of Tujia folk-song transmission suggests that the maintenance of cultural-memory is supported by processes that are significantly more complex than has been realized. The critical combination of ethnographic, biometric, cognitive and network-based data make it clear that the perpetuation of intergenerational knowledge transmission is dependent on the selective reconstruction of four psychocultural states, including embodied synchrony, ritual embeddedness, semantic coherence and social connectivity, as opposed to the mere reenactment of melodic or lyrical elements. There is cause for concern in the Tujia musical legacy, according to quantitative data. The composite retention rate fell between the youth (0.460) and the seniors (0.915), and around 60% of the transmission sites were concentrated around the old culture carriers. Evidently, the Tujia musical legacy is in grave danger of collapsing under the weight of these findings. The cultural DNA of these traditions has been radically altered due to the high rate of erosion over invention (77.9% in linguistic analysis and 81.1% in symbolic meaning), which suggests that the transmission patterns have not evolved naturally. Nonetheless, potential intervention strategies are highlighted by the substantial connection (r = 0.74) between emotional synchrony and memory retention. According to new research, the best conditions for deep cultural encoding to take place are those in which there is physiological synchrony developed within the framework of shared rituals and embodied practice. Such proof poses a threat to the status quo of preservation paradigms that prioritize archival documentation over first-hand accounts. A model for systematizing the study of cultural practices in risk across the world has emerged thanks to recent methodological breakthroughs, the most notable of which are MGTA, Digital Cognitive Mapping, Biometric Coding, and Network Analysis. To elevate heritage preservation from an ad

hoc, practitioner-based method to a more scientific, evidence-based one, these tools are necessary for the precise identification of transmission-related risks and the development of evidence-based interventions. Instead of only collecting and preserving physical artifacts, researchers have found that true oral tradition preservation necessitates actively recreating the social and psychological environments that fostered the traditions in the first place. Future research should be able to question the ways in which digital technologies can only supplement but not replace embodied transmission, and how diaspora communities have contributed to the maintenance of a cultural continuity in situations of geographic displacement and social change.

Conflict of interest

The authors declare no conflict of interest.

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