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Unraveling minnan imagery: a comprehensive analysis of traditional and modern minnan nursery rhymes through complex networks

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Abstract

Nursery rhymes provide insights into the traditions, beliefs, and values of a culture, thereby making it an integral part of a community's heritage. As representative linguistic resources within the intangible cultural heritage of the Hoklo people, Minnan nursery rhymes (MNRs) play a crucial role in connecting the Chinese mainland, Taiwan Strait, and overseas Chinese communities. This study delves into features of 617 traditional and 289 modern pieces through text mining techniques, including text segmentation, the TF-IDF (term frequency-inverse document frequency) method, and the complex network analysis. We examine the frequency and emotional purity of lyrics at a larger scale than previous studies using a small set of manually annotated samples. Furthermore, we analyze the patterns of MNRs by assessing the overall, individual, core-periphery structures of the constructed MNR networks, considering key terms as nodes and co-occurrence relationships between nodes as links. Our investigation reveals the heterogeneous nature of terms in both traditional and modern MNR networks. Moreover, through the community detection method, we identify five primary imagery features presented in MNRs. Traditional MNRs place emphasis on family relationships, folk culture, and food culture, reflecting enduring aspects of Minnan cultural heritage. In contrast, modern MNRs pivot towards themes of children's emotions and natural scenery, indicative of evolving societal values. This study represents the first large-scale complex network analysis of MNRs, providing valuable insights into the embedded Minnan culture and serving as a foundation for further research into the societal dynamics reflected in these cherished MNRs resources.

Keywords Minnan nursery rhyme, Complex network, Minnan culture, Text mining, Natural language processing

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Introduction

Intangible cultural heritage (ICH) is a crucial component of human culture, representing the accumulation of human civilization and wisdom. In 2003, UNESCO adopted the Convention for the Safeguarding of the ICH, which greatly contributed to the protection and record of ICH in the world [1]. After two decades of continuous exploration and efforts, ICH protection work has achieved fruitful results, including a series of word-level protection items, such as Chinese Kunqu, Spanish Flamenco, and Indian Kutiyattam. As of December 2023, the UNESCO Representative List of the ICH of Humanity included 730 heritage projects from 145 different countries [2]. Minnan nursery rhymes (MNRs), created as songs for children, are recognized as an artistic form within the "oral traditions and expressions" domain of UNESCO's 2003 Convention for the Safeguarding of the ICH [1]. MNRs are categorized into this domain as they are traditional forms of oral literature, usually specific to a culture, region, or language group. As a crucial part of cultural traditions, MNRs are transmitted from generation to generation, typically through informal ways such as family members, educational settings, community events, or various media platforms.

MNRs encompass a rich and enduring legacy that spans from the Tang Dynasty to the contemporary era. Local historical classics from the Tang Dynasty (618–907) documented a nursery rhyme called "Yue guang guang," which celebrated the beauty of moonlight [3, 4]. As many Minnan residents traveled to Taiwan and Southeast Asia, they carried with them their treasured MNRs. This cultural exchange allowed for the spread of these rhymes far beyond the borders of Fujian throughout the Song, Yuan, Ming, and Qing dynasties (960–1911) [5]. These MNRs have been handed down through generations and are often steeped in folk wisdom and values. Moreover, MNRs not only embody the ancient Chinese people's creative spirit, but they also vividly depict various aspects of Minnan folks' life, such as scene descriptions of rural work and local traditions [6]. MNRs are typically simple, rhythmic, and melodic, which suits children's cognitive and psychological development[7]. As such, MNRs represent a key linguistic component of Minnan ICH and are an essential and irreplaceable part of Chinese folk culture [8]. These rhymes encompass a wide variety of themes, including but not limited to politics, family relationships, local customs, and child rearing [9]. Additionally, they can be categorized by their form of performance, such as "ChangYao(念谣)"— a form of oral storytelling, and "WuYao(舞谣)"— involved dancing with the rhymes[10]. However, the MNRs are at serious risk of being extinct due to the forces of cultural globalization. To protect and preserve the MNRs, they were inscribed onto the second batch of the National List of Intangible Cultural Heritage in China in 2008 [11].

To enable MNRs to be appreciated and perpetuated by future generations, researchers try to awaken people's attention to MNRs from multidimensional perspectives, such as educational and economic values [6]. Many studies have explored the embedded literature connotation and history values of MNRs through qualitative analysis of individual or a small set of similar MNRs. By concentrating on a few selected examples, such research can provide deep insights into the literary, artistic, and cultural significance of each rhyme. However, this approach may overlook patterns, trends, and features common across the broader spectrum of MNRs. To address this limitation, researchers have employed the complex network theory, which examines the interrelationships among individuals and their structural characteristics, to ensure a well-rounded understanding and appreciation of cultural heritage [12–14]. Li et al. probed the modern-age evolutionary path of the Gulangyu community's spatial layout using network theory, supplemented by interpreting historical maps and assimilating historical geographic data [15]. Liu et al. constructed a cultural cluster innovation network through the complex network to analyze the structural characteristics and spatial-temporal evolution process of Chinese cultural industry clusters [16]. Li et al. investigated the character social networks of *Harry Potter* and *The Lord of the Rings* via complex network theory, which not only showed a new perspective on literary analysis but also presented an intriguing interdisciplinary approach bridging the gap between literary studies and network science [17]. Li et al. modeled character relationships within Cao Xueqin's novel named *A Dream of Red Mansions* using the complex network method, and their results show that the diameter of the character relationship satisfies the real-world social relationship structure–six-degree separation theory [18]. Although the utilization of complex network theory in the study of MNRs (MNRs) is rare, these existing researches support the premise that the complex network methodology has considerable potential in extracting high-dimensional cultural connotations from MNRs datasets. Consequently, this can significantly enhance the efforts for the preservation, comprehension, and communication of the intricate layers of information inherent in MNRs.

Based on that, this study employs complex networks to conduct a comprehensive study of the lyric features, expression patterns, and embedded imagery of both traditional (created before the 1950 s) and modern MNRs (created after the 1950 s), aiming to foster a deeper understanding and appreciation of these cultural treasures. Utilizing two types of datasets–traditional and modern MNRs, we first preprocess the dataset, and

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then analyze the word cloud and emotion entropy of the terms in the nursery rhyme lyrics. We further construct networks for traditional and modern MNRs, representing lyric keywords as nodes and their co-occurrences as connecting edges. Moreover, we explore the network features, investigate core-periphery structures, and perform community detection to uncover the inherent imagery characteristics in MNRs, such as social norms, folk culture, and historical context. The paper is organized as follows. Sect. 2 introduces work related to this study. Sect. 3 and 4 outline the datasets and research methods. Section 5 presents the lyrical information of MNRs and the analysis of constructed MNR networks. Section 6 explores the imagery characteristics of traditional and modern MNR networks through community detection. Subsequently, Sect. 7 discusses the evolution and values of MNRs, as well as the limitations of this study. Finally, we conclude key findings and future research direction in 8.

Related work

Over the past twenty years, significant progress has been made in data mining and knowledge discovery using complex networks, driven by the increasing demand for big data analytics. This growth is not limited to more conventional areas, but also encompasses interdisciplinary areas such as social systems and medical research. Boccaletti et al. have applied complex network analysis to study social networks, identifying influential nodes, community structures, and information diffusion patterns within social media platforms[19]. Barabási et al. discussed the application of network science to understand the pathogenesis of disease and discover new drug targets [20]. Olaf Sporns explored the structure and function of the brain system by complex network theory, shedding light on topics such as brain connectivity and neurological disorders [21]. Despite the differences among social, disease, and brain systems, these systems can be modeled as complex networks composed by elements called nodes (or vertices) and a set of connecting links (edges) that represent their interactions.

Works in the field of complex networks also delve into interdisciplinary topics like literature and art. Weng et al. have constructed complex networks based on interactions between characters in literary works [22–24]. By analyzing the connections and relationships between characters, they gain insights into narrative structures, character dynamics, and thematic elements. In the realm of art history, researchers have applied complex network analysis to understand the influence and diffusion of artistic styles, techniques, and movements. Buk et al. applied complex networks to probe poetic forms, rhythms, and stylistic variations across different poets

and time periods [25, 26]. Smolla and Akçay modeled culture as networks of ideas that were distributed among members of a population [27]. The significance of complex networks lies in their ability to combine qualitative description and analytical quantitative, making them a unified framework for the exploration of complex systems across various domains.

Though the studies discussed above have highlighted the usefulness of complex networks for knowledge discovery in various research fields, current research primarily focuses on individual or small sets of MNRs using qualitative analysis to explore different aspects, such as the historical origins, literary elements, educational significance, cultural preservation, and social functions. Xu et al. delved into the historical origins and cultural connotations of MNRs, that they were rooted in farming civilization, flourished in village society, and were intricately woven into the living habits and cultural characteristics of the Minnan people [28–30]. They also unveiled that MNRs first appeared in the Tang Dynasty [3] and journeyed to Taiwan and Southeast Asian countries during the middle and late Ming Dynasty as the migration of the Minnan people. Chen et al. explored the protection and inheritance of MNRs as intangible cultural heritage [6, 31, 32]. Scholars have put forward protective strategies, such as organizing competitions and creating digital animation films of MNRs, within the framework of digital media strategy and creative products [33]. They have also stressed the importance of integrating government and community resources to aid in the preservation of MNRs. Zhang et al. discussed the integration of MNRs in early childhood education and elementary school music teaching to deepen children's understanding and interest in local culture [34–36]. Wang explored ways to improve the influence and promote the spreading of MNRs in modern society [37]. Chen designed MNR picture books through new information technology, augmented reality, which enhanced the expression of MNRs characteristics beyond the limitations of traditional education books, thus improving the influence of MNRs [38]. Lin et al. proposed to improve the spreading of MNRs through situational H5 animation and IP design [33]. Despite the above prospects, the values and functions of MNRs were also explored in [6, 31, 39]. For example, Zhu studied how MNRs functioned as moral tools to transmit values and norms[39], and contributed to community cohesion and identity formation. Chen explored the use of MNRs as political messaging vehicles in the context of cross-strait relations between mainland China and Taiwan [31].

The studies discussed have explored MNRs from various perspectives. However, few have offered quantitative knowledge mining on aspects such as word frequency, conveyed emotions, and expressed imagery within

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Table 1 The dataset of MNRs

Traditional MNRs		Modern MNRs	
Content type	Count	Content type	Count
Folk custom	16	Folk custom	12
Family relationship	16	Daily life	13
Lullaby	26	Plants and animals	16
Etiquette ceremony	36	Games	21
History and politics	63	History and politics	30

MNRs. Drawing inspiration from the above interdisciplinary studies utilizing complex networks, this research seeks to reveal the lyrical characteristics, expression patterns, cultural significance, and evolution of MNRs through complex network theory.

Data
The research data in this paper encompasses two types of MNRs: traditional (created before 1950 s) and modern MNRs (created after 1950 s). By examining these two aspects, this study can delve into their differences and explore the evolution of MNRs over time and the influence of society development on MNRs. We use a collection of MNRs edited by experts Yuping Jiang, Changji Zhou, and Qinghai Zhou [40–42], as well as internet sources. The MNRs edited by experts in the field of Minnan culture ensure the accuracy and reliability of the data. Moreover, internet sources can provide access to a broader range of MNRs, which helps explore variations, interpretations, and even uncover

lesser-known MNRs that might not be included in edited collections. After manually selecting and removing duplicates, we have obtained a total of 617 traditional MNRs and 289 modern MNRs. The MNRs are categorize into different content types by domain experts, and Table 1 shows five of them.

Methodology
Overall framework
As shown in Fig. 1, our approach comprises three main parts: data pre-processing, lyrical term analysis, and complex network analysis. In the data pre-processing step, we sequentially process the lyrics of MNRs through text segmentation and the TF-IDF (term frequency-inverse document frequenc) method. Subsequently, we utilize techniques such as word cloud generation and information entropy to analyze the characteristics of lyrical terms. Finally, in the complex network analysis phase, we define various measures, including network characteristic indicators, degree distribution, core-periphery analysis, and community detection.

Data pre-processing
We outline tailored processing steps for the lyrics of MNRs, as specific characteristics exist in the lyrical texts, including a mixture of written Chinese (both simplified and traditional) and written Hokkien (a written form of the Minnan language).
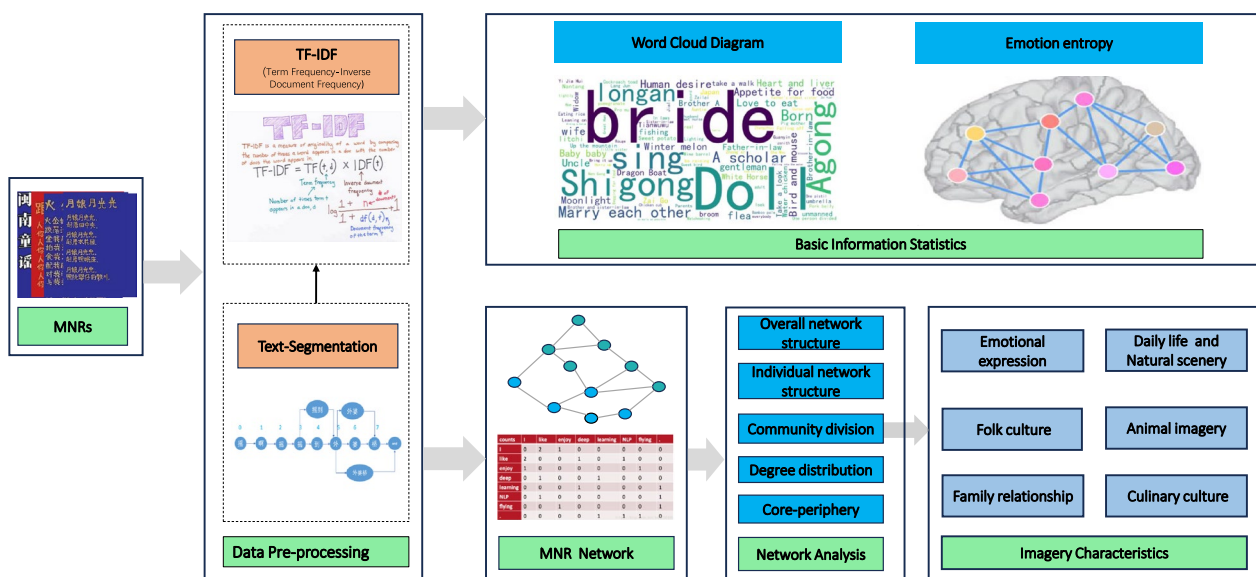

Fig. 1 Research framework

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(1) Language Standardization: This step standardizes the MNRs dataset by converting all lyric texts into simplified Chinese, which ensures consistency and ease of processing.

(2) Removing Irrelevant Characters: By removing irrelevant characters such as special characters and punctuation, the lyrical text is streamlined, and further steps can focus solely on elements contributing to understanding the lyrics.

(3) Custom Dictionary: Traditional text segmentation methods might not accurately handle non-Chinese texts, particularly those in the Minnan language. Therefore, we create an integrated Chinese-Minnan dictionary to allow for more accurate tokenization.

(4) Lyrics Segmentation and Post-processing: The LTP (Language Technology Platform) is employed to segment the lyrics into meaningful units. To enhance the accuracy of the segmented lyrical terms, the post-processing, like filtering out noise, irrelevant tokens, and correcting segmentation errors, is applied to refine the segmented tokenization.

(5) Keyword Extraction: By calculating the TF-IDF values, the critical terms of lyrics are identified based on the obtained TF-IDF values.

Lyrical term analysis method
Word clouds
After the pre-processing algorithm TF-IDF on assessing the significance of terms in section 4.2, the word cloud technology is applied to discern main themes or trends of the MNRs' lyrics based on the obtained TF-IDF values. Subsequently, these lyrical terms are visually represented in a cloud diagram, with their sizes adjusted proportionally to their significance.

Emotion entropy
A song typically conveys either positive or negative emotions. Instead of discussing the emotional tendency of a rhyme, we delve into the emotional preference of words extracted in 4.2. The emotion category of a word is usually context-dependent, and it may have the opposite emotion category in different contexts [43, 44]. Furthermore, in the MNRs, many lyrical words are not included in traditional categories of emotions, and they do not express direct positive or negative feelings, like the negative word "anger" and the positive word "amusement". In this study, the emotions of lyrical words are determined by deep-learning technology and experts. Specifically, a supervised-learning based skip-gram model is employed to train word vectors based on large-scale text. Triples *(a word/phrase, sentence in which word/phrase is located, sentiment category of the word/phrase)* are used as the training samples of the model. The training set is obtained by integrating the NTUSD,[1] HowNet[2] dictionaries, and experts-designed dictionaries. The emotion category of lyrical words are automatically predicted by the trained skip-gram model. Crucially, the predicted sentiment categories are then verified by domain experts, ensuring the credibility of the predictions.

To tackle the issue of a lyrical word potentially having contrasting emotional classes in different lyrical sentences, we define the concept of "emotion entropy" to describe the emotional preference of a word. Specifically, emotion entropy quantifies the degree to which a word is associated with a specific (pure) emotion-positive or negative-instead of an ambiguous emotional connotation [45]. We define two possible emotional states of a word (x) as positive (x_1) and negative (x_2), and $p(x_1)$ is the probability that the word x conveys a positive emotion. In contrast, $p(x_2)$ is the probability that the word conveys a negative emotion. Therefore, the emotion entropy $H(x)$ of the word (x) could be defined as formula 1 by using the Shannon entropy formula [46]. It is noticeable that the emotions (positive or negative) of some words are labeled by a deep neural network model (Long short-term memory neural network) and validated by experts.

$$H(x) = -p(x_1) \log_2 p(x_1) - p(x_2) \log_2 p(x_2) \qquad (1)$$

As shown in formula 1, a higher value of emotion entropy indicates that the emotional connotation of a word is more uncertain or unpredictable, suggesting it is less emotionally pure. Conversely, a word with a lower value indicates a more precise emotional connotation or higher "emotion purity," so the probability of this word conveying either positive or negative emotion is more heavily inclined toward one particular emotion.

Complex network analysis method
We introduce the construction of MNR networks in section 4.4.1 and provide measures of complex networks in section 4.4.2.

The construction of MNR networks
In this section, we construct a Minnan nursery rhyme network (abbreviated as MNR network) by representing lyrical keywords as network nodes and capturing the co-occurrence relationships between nodes as edges. The processes involved in constructing and analyzing the MNR networks are listed as follows: (1) Building the Vocabulary: A vocabulary is created, comprising all unique terms extracted in section 4.2. This step aims to eliminate duplicates and

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[1] http://nlg.csie.ntu.edu.tw/nlpresource/NTUSD-Fin/
[2] https://www.heywhale.com/mw/dataset/6113895baca2460017a475be/file.

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organize the vocabulary in a structured manner for constructing a co-occurrence matrix.

(2) Co-occurrence matrix generation: The co-occurrence matrix is constructed based on the frequency of occurrence of each keyword pair within the lyrics. Each row and column of the matrix corresponds to a unique keyword from the vocabulary. The value at the intersection of a row and column represents the frequency with which the corresponding keywords co-occur within the nursery rhymes.

(3) MNR network construction: Each unique keyword is assigned as a node, and the co-occurrence relationships between keywords are depicted as edges. Whenever two keywords appear together in a nursery rhyme, they are regarded as having a co-occurring relation. The weight of an edge is determined by the frequency of their co-occurrence.

The definition of network measures

Overall network characteristic indicators We explore the overall network characteristics of the MNR networks by indicators: network density, average clustering coefficient, and average path length. Analyzing these indicators allows us to discern patterns, trends, and emergent properties within the network, enriching our understanding of linguistic and cultural contexts within MNRs. We assume N and E denote the number of nodes and edges for simplifying the following definitions.

A. Network density Network density is to measure the level of connection density among nodes, with higher values indicating denser connections [47]. It can be quantified by the equation 2, where ρ represents the network density.

$$\rho = \frac{2E}{N(N-1)} \tag{2}$$

B. Average clustering coefficient The average clustering coefficient quantifies the tendency of nodes to form clusters or groups within a network, with values ranging from 0 to 1 [48]. A higher coefficient signifies closer connections between nodes and a more clustered network. This indicator is commonly used to analyze network community structure, evolution processes, and randomness. The definition of the average clustering coefficient C is provided in the formula 3, where the c_i represents the clustering coefficient of node i.

$$C = \frac{1}{N} \sum_{i=1}^{N} c_i \tag{3}$$

C. Average path length   The average path length of networks is employed to estimate the average efficiency of information delivery in a network [49]. As defined in

the formula 4, the average path length L is calculated as the average number of shortest path lengths along the shortest paths for all possible pairs of network nodes. The symbol d_{ij} in the formula 4 denotes the shortest path length between node i and node j.

$$L = \frac{1}{N(N-1)/2} \sum_{i \neq j} d_{ij} \tag{4}$$

Individual network characteristic indicators   In network theory, individual network characteristic indicators provide valuable information about individual nodes and their roles within a network [50], allowing for a better understanding of the behavior and functionality of nodes. In the following measures, we denote the adjacency matrix and the weight matrix of a network as **A** and **W**.

A. Degree centrality The degree of a node refers to the number of connections that a node has in a network, where a higher value indicates its prominence and influence within the network [51–53]. The node degree is defined as the formula 5. The element A_{ij} of the adjacency matrix **A** is defined as 0 if there is no link between node i and node j, and $A_{ij} = 1$ if a link exists between them.

$$D_i = \sum_{j=1}^{N} A_{ij} \tag{5}$$

B. Weighted degree centrality The weighted degree is a variant of the degree centrality [51–53], as defined in formula 6. It takes into account the weights associated with the edges between nodes, which W_i is the weighted degree of the node i, and ω_{ij} represents the weight of the node between i and j.

$$W_i = \sum_{j=1}^{N} \omega_{ij} \tag{6}$$

C. Betweenness centrality The betweenness centrality measures the extent to which a node lies on paths between other nodes in a network. Nodes with high betweenness centrality act as crucial bridges or connectors, facilitating the flow of information and resources between different parts of the network [51–53]. The formula 7 shows how to calculate betweenness centrality, where N_{st} represents the number of shortest paths from node s to t, and $N_{st}(i)$ denotes the number of shortest paths passing through node i.

$$S_i = \sum_{s \neq i \neq t} \frac{N_{st}(i)}{N_{st}} \tag{7}$$

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D. Closeness centrality Closeness centrality detects how close a node is to all other nodes in the network [51–53]. The closeness centrality of a node in formula 8 is quantified as the average of the shortest path length from the node to other nodes in the network. Nodes with high closeness centrality tend to have shorter average path lengths to other nodes, allowing for efficient information dissemination and quick access to resources. The variable B_i represents closeness centrality, where N is the total number of nodes and $\sum_{j=1}^{N} d_{ij}$ represents the distance from node i to all other nodes.

$$B_i = \frac{N-1}{\sum_{j=1}^{N} d_{ij}} \tag{8}$$

E. Eigenvector centrality Eigenvector centrality assesses a node's importance within a network not solely by its direct connections but also by the importance of its neighboring nodes [54, 55]. Consequently, nodes with high eigenvector centrality are usually linked to other important and influential nodes. This measure is especially useful for identifying influential nodes that are influential in the network, even if they do not have many direct connections. We assume that M_i represents the eigenvector centrality of node i, and it is defined as follows,

$$M_i = \frac{1}{\lambda} \sum_{j=1}^{N} A_{ij} x_j \tag{9}$$

where λ is the eigenvalue eigenvector associated with M_i.

Degree distribution   In complex networks, degree distribution is viewed as a critical metric for characterizing network structure. It is the probability distribution of node degrees over the entire network. The power-law characteristic of degree distribution has attracted significant academic interest due to its prevalence across a wide array of natural and artificial systems, such as urban traffic [56], earthquake magnitudes [57], and power outage extents [58]. When the degree distribution of a network follows a power-law relationship, the probability $P(k)$ of nodes with degree k is characterized by $P(k) \propto k^{-\gamma}$ as defined in formula 10, where the γ is the power-law exponent [59]. As shown in formula 10, the inverse relationship indicated by the negative exponent $(-\gamma)$ implies that there are many nodes with a small number of connections and only a few nodes with a large number of connections.

$$P(k) = k^{-\gamma} \tag{10}$$

By taking the logarithm of both sides of the formula 10, we derive the relationship as $\log(P(k)) = -\gamma \log(k) + r$ presented in formula 11. Here, the constant r represents

any multiplicative factors that might have been present in the original equation before taking the logarithmic transformation.

$$\log(P(k)) = -\gamma \log(k) + r \tag{11}$$

Core-periphery structure   The core-periphery structure of complex networks typically consists of a densely connected core and a sparsely connected periphery [60]. The "core" consists of a highly interconnected group of nodes, which often play crucial roles in the network's function and dynamics. The "periphery" contains nodes with fewer connections, typically connected to the rest of the network through the core nodes. Other nodes within the network belong to the set of "semi-periphery". This core-periphery structure can influence the robustness of a network, the efficiency of information or resource transfer, and the overall behavior of the network.

In a network, it is assumed that the coreness value of node i is C_i. The overall average coreness of the network is represented by C_{mean}, and the standard deviation of the network coreness is denoted as C_{sd}. As shown in formula 12, a node i belonging to one of the three types "core", "periphery", or "semi-periphery" is defined as its coreness value C_i relative to the network's average coreness C_{mean} and standard deviation C_{sd}.

$$i \in \begin{cases} \text{core node} & \text{if } C_i \geq C_{\text{mean}} + C_{\text{sd}}, \\ \text{semi-periphery node} & \text{if } C_{\text{mean}} + C_{\text{sd}} > C_i > |C_{\text{mean}} - C_{\text{sd}}|, \\ \text{periphery node} & \text{if } C_i \leq |C_{mean} - C_{sd}|. \end{cases} \tag{12}$$

Community structure   Community structure in complex networks is characterized by organizing nodes into clusters. The connections within each cluster are dense, while connections are sparser between clusters. The Louvain algorithm [61], as one of the most popular community detection algorithms, is to find communities in a network by optimizing the modularity score, which quantifies the strength of the division of a network into communities. Higher modularity values indicate a more robust partitioning of the network into communities. The modularity of the given partition of a network is defined as formula 13, where γ is the resolution parameter, and the $\sigma(c_i, c_j)$ is 1 if nodes i and j are in the same community else 0 [62].

$$Q = \frac{1}{2m} \sum_{ij} \left(A_{ij} - \gamma \frac{k_i k_j}{2m} \right) \delta(c_i, c_j) \tag{13}$$

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(a) Traditional MNRs

(b) Modern MNRs

Fig. 2 MNRs word cloud diagram

Results

Basic information statistics

Analysis of word cloud

The word cloud diagram is a visualization technique that summarizes the textual content by presenting high-frequency words prominently [63]. As shown in Fig. 2, the main themes in the MNRs lyrics are illustrated through the word cloud diagram. In such a diagram, the size of a word is proportional to its frequency of occurrence in the text, which means that more common words appear more prominent and bolder, while less common words are displayed smaller. Analysis of Fig. 2a reveals that significant terms, such as "bride (新娘)," "longan (龙眼)," and "Taoist priest (师公)" within traditional MNRs. Conversely, Fig. 2b highlights terms like "body (身体)," "funny (有趣)," and "Taiwan (台湾)" as prevalent words within modern MNRs.

Analysis of emotion entropy

Table 2 presents the top 10 words ranked by their respective emotion entropy for both traditional and modern MNRs. Within the traditional MNRs, the term "bride (新娘)" possesses the highest emotion entropy, succeeded by words such as "doll (公仔)," "sing (唱歌)" and "longan (龙眼)." Specifically, the term "bride", for instance, is frequently found in MNRs depicting familial affection, illustrating unique wedding customs, or narrating romantic tales. It is noticeable that, as shown in Table 2, the emotion entropy of the top ten terms in the modern MNRs is much lower than that in traditional MNRs. The emotion entropy of the term "like (像是)", which ranks first with the highest emotion entropy in modern MNRs, is actually lower than that of the term "kids (婴仔)" in traditional MNRs. Specifically, "like (像是)" and "kids (婴仔)" have emotion entropy of 0.0041 and 0.0092, respectively. This result shows that modern MNRs express more homogeneous emotions

than traditional MNRs. Furthermore, it suggests a shift in emotional expression over time within these analyzed corpora.

Network analysis

Analysis of overall network indicators

We apply the methodology delineated in Sect. 4.4.1 to construct networks for traditional and modern MNRs. The resulting traditional MNR network comprises 757 nodes and 15,874 edges, while the modern MNR network contains 745 nodes and 4,964 edges. Table 3 presents the overall characteristics of both networks. The traditional MNR network has a density of 0.055, indicating a sparse structural organization. Despite its general sparsity, an average clustering coefficient of 0.524 means the presence of community structure within the network. Furthermore, with an average path length of 2.269, nodes are 2–3 hops apart on average, suggesting the network has a relatively interconnected nature. Conversely, the network density of the modern MNR network is 0.018, indicating a much sparser structure. The average clustering coefficient is 0.781, suggesting the existence of more pronounced community structures, whereas the average path length of 3.33 reflects a larger number of intermediary hops required to connect any pair of nodes. In summary, these characteristics in Table 3 indicate that both traditional and modern networks display overall sparsity in connectivity, yet each possesses strong internal linkages and pronounced community structure.

Analysis of individual network indicators

Tables 4 and 5 present the calculated values of five key indicators (i.e., node degree, node weighted degree, betweenness, closeness, and eigenvector centrality) for the top-20 word nodes within traditional and modern MNR networks.

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Table 2 Node emotion entropy of MNRs Network

Rank	Traditional MNRs		Modern MNRs	
	Terms	**Emotion entropy**	**Terms**	**Emotion entropy**
1	Bride(新娘)	0.0236	Like(像是)	0.0041
2	Doll(公仔)	0.0161	Sometime(有时)	0.0037
3	Sing(唱歌)	0.0135	People(大家)	0.0033
4	Longan(龙眼)	0.0126	Someone(有人)	0.0027
5	Scholar(秀才)	0.0117	What(什么)	0.0027
6	Auntie(婶婆)	0.0114	Body(身体)	0.0027
7	Mouse(鸟鼠)	0.0102	One(一只)	0.0026
8	Flea(虼蚤)	0.0102	Funny(有趣)	0.0024
9	Bright moonlight(月光光)	0.0096	Taiwan(台湾)	0.0020
10	Kids(婴仔)	0.0092	Ours(我们)	0.0021

Table 3 Overall indicators of MNRs network

Category	Nodes	Edges	Network density	Average clustering coefficient	Average path length
Traditional MNRs	757	15874	0.055	0.524	2.269
Modern MNRs	745	4964	0.018	0.781	3.33

As shown in Table 4, the ranked 20 most important terms are similar under the five centrality measures. The word "bride (新娘)" is the most influential one, as it ranks first under the five centrality indicators. In addition, some specific words, including " longan (龙眼)," "litchi (荔枝)," "mouse (鸟鼠)," "grandaunt (婶婆)" and "wife (老婆)" also display high centrality across all examined indicators. These words represent crucial elements associated with an idyllic picture of life and distinctive cultural themes in the Minnan region, encompassing family relationships, animals, and local produce such as vegetables and fruits. It is observed that household items, such as "broom (扫帚)" and "winnowing basket (簸箕)," along with terms related to wedding traditions like "matchmaker (媒婆)" and "the elder woman (婆仔)," increase in both weighted degree and eigenvector centrality rankings. The rise in rank of these terms reflects their growing importance and prevalence in the sociocultural lexicon within traditional MNRs. The betweenness and closeness rankings of terms such as "kids (婴仔)," "Guanyin (观音, the Bodhisattva of compassion in Chinese Buddhism)" and "general (将军)" not only imply their frequent usage but also underscores the unique historical narratives and cultural values in the traditional MNRs.

By analyzing indicators of the modern MNR network, the words "funny (有趣)" and "joyful (欢喜)" are ranked first with the five centrality measures in Table 5.

In addition, many positive semantic words like "cute (可爱)," "interest (趣味)," "beauty (美丽)," and "clean (干净)" appear in the top-20 rankings. This illustrates the intent of lyricists to compose songs aimed at evoking a sense of joy specifically for children. Additionally, the words related to people, such as "friend (朋友)," "grandfather (阿公)," and Flora and fauna in nature like "trees (树木)," "garden (花园)," "sun (太阳)," "flower (花朵)" indicates that modern MNRs incorporate a solid connection to social and environmental themes. In terms of weighted degree and betweenness centrality, the rise in the rankings of "similar (亲像)" and "a modal particle to express degree (巴巴)" suggests an emphasis on the rhetorical device in the modern MNRs. The use of such words enhances the vividness of the narratives and leaves a more lasting impression on the children who recite them. Furthermore, the increase in eigenvector centrality rankings for words like "Smiling Mimi (笑咪咪)" and "Smiling Xixi (笑嘻嘻)" both related to laughing, again reinforces the presence of joyful emotion in these rhymes. The rising rank of eigenvector and closeness centrality for animal-related terms like "dolphin (海豚)" and "cat (猫咪)" shows the animal scenes in MNRs, which are common themes in children's literature and are known to capture their attention and stimulate their imagination. Both traditional and modern MNRs capture various aspects of the Minnan people's life. However, the traditional MNRs emphasize

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Table 4 Centrality rankings of top-20 node words in the traditional MNR network

Rank	Degree	Node	Weighting degree	Node	Betweenness centrality	Node	Eigenvector centrality	Node	Closeness centrality	Node
1	166	Bride (新娘)	1432	Bride (新娘)	0.101	Bride (新娘)	1.000	Bride (新娘)	0.519	Bride (新娘)
2	122	Longan (龙眼)	714	Litchi (荔枝)	0.058	Heart (心肝)	0.786	Longan (龙眼)	0.489	Heart (心肝)
3	109	Heart (心肝)	684	Doll (公仔)	0.056	Longan (龙眼)	0.745	Wife (老婆)	0.489	Longan (龙眼)
4	109	Wife (老婆)	670	Mouse (鸟鼠)	0.040	Litchi (荔枝)	0.674	Mouse (鸟鼠)	0.479	Wife (老婆)
5	102	Litchi (荔枝)	654	**Broom** (扫甫)	0.039	Wife (老婆)	0.653	Litchi (荔枝)	0.470	Mouse (鸟鼠)
6	88	Mouse (鸟鼠)	640	Grandaunt (婶婆)	0.037	Scholar (秀才)	0.643	Heart (心肝)	0.469	Litchi (荔枝)
7	86	Doll (公仔)	624	Longan (龙眼)	0.034	**Kids** (婴仔)	0.631	Grandaunt (婶婆)	0.467	Grandaunt (婶婆)
8	85	Umbrella (雨伞)	616	Wax gourd (冬瓜)	0.033	**Guanyin** (观音)	0.613	Umbrella (雨伞)	0.463	Magpie (客鸟)
9	83	Grandaunt (婶婆)	610	Scholar (秀才)	0.030	Parents (爸母)	0.558	Pomegranate (石榴)	0.462	Umbrella (雨伞)
10	83	Scholar (秀才)	598	Wife (老婆)	0.030	Doll (公仔)	0.556	Doll (公仔)	0.459	Doll (公仔)
11	72	Dragon boat (龙船)	590	**Fishing** (钓鱼)	0.028	Grandaunt (婶婆)	0.543	Wax gourd (冬瓜)	0.455	Dragon boat (龙船)
12	72	Pomegranate (石榴)	578	The elder woman (婆仔)	0.027	The elder woman (婆仔)	0.515	**Winnowing basket** (簸箕)	0.454	Scholar (秀才)
13	71	Bright moonlight (月光光)	568	Heart (心肝)	0.026	**Edible frog** (水鸡)	0.502	Scholar (秀才)	0.453	Wax gourd (冬瓜)
14	70	Wax gourd (冬瓜)	548	**Tonneau** (酒桶)	0.024	**Moonlight** (月光)	0.496	Dragon boat (龙船)	0.452	Bright moonlight (月光光)
15	68	The elder woman (婆仔)	532	Dragon boat (龙船)	0.024	Mouse (鸟鼠)	0.483	Bright moonlight (月光光)	0.451	**Relatives by marriage** (亲家)
16	67	Magpie (客鸟)	532	Father-in-law (文人)	0.023	Dragon boat (龙船)	0.482	**Matchmaker** (媒人)	0.447	**Rooster** (鸡角)
17	67	Chair (交椅)	526	Pomegranate (石榴)	0.023	**Sweet potato** (番薯)	0.470	**Garlic chives** (韭菜)	0.447	An ancient folding chair (交椅)
18	67	Father-in-law (文人)	482	**Brother-in-law** (舅夫)	0.022	Magpie (客鸟)	0.465	**Broom** (扫甫)	0.444	The elder woman (婆仔)
19	66	Parents (爸母)	476	**Toad** (蟾蜍)	0.022	Umbrella (雨伞)	0.463	Father-in-law (文人)	0.444	**Edible frog** (水鸡)
20	66	Mother-in-law (家娘)	450	Parents (爸母)	0.021	**General** (将军)	0.462	**Peach blossom** (桃花)	0.444	Parents (爸母)

Words highlighted with bold font are new important words that are not included in the measure of node degree

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family ties and distinct cultural values, whereas modern MNRs mainly depict delightful feelings.

Analysis of degree distribution

We present the node degree distribution for both the traditional and modern MNR networks in Fig. 3. In panels (a) and (b), we utilize the maximum-likelihood fitting method proposed by Clauset et al. [64, 65] to assess whether a distribution conforms to a power-law distribution. The blue circles represent the degree distribution of MNR networks in a log-log coordinate system, while the black dotted line denotes the best fit to the empirical distribution based on the Kolmogorov-Smirnov statistic and likelihood ratios [66]. As shown in Fig. 3, the blue and yellow circles coincide with the black power-law fitting line, suggesting that the node degree of traditional and modern MNR networks conforms to a power-law distribution (also known as long-tailed distribution).

Analysis of core-periphery network structure

Analysis of core-periphery structure for both traditional and modern networks is presented in Table 6. The correlation coefficients between the observed networks and the ideal core-periphery pattern matrix are 0.54 for the traditional MNR network and 0.68 for the modern MNR network. The observed coefficients suggest a strong correlation, indicating a pronounced core-periphery structure. The multiplicative coreness score ranges from 0 to 1, and nodes with higher scores will be positioned at the center of a network [60]. In the traditional MNR network, coreness scores of nodes span from 0 to 0.227, with an average value of 0.029. In contrast, the modern MNR network exhibits coreness scores between 0 and 0.377, with a mean score of 0.021. Using the defined criteria in formula 12, we categorize the network nodes into core, semi-periphery, and periphery node sets. As shown in Table 6, the proportion of core nodes is 7.2% in the traditional MNR network and increases to 8.2% in the modern MNR network. The percentage of semi-periphery nodes is 46.3% in the traditional MNR network and 32.7% in the modern MNR network. Additionaly, the traditional MNR network has a considerably lower percentage of periphery nodes at 46.5%, compared to the 59.1% observed in the modern MNR network.

By employing the Fruchterman Reingold visualization of Gephi software on traditional and modern MNR networks, the Fig. 4 marks word nodes in the core set with green color, while the semi-periphery and periphery node sets are denoted by orange and purple color, respectively. In the traditional MNR network, core nodes are densely interconnected and mainly describe themes related to folkloric culture, food culture, and emotion expression. Specifically, the terms such as "bride (新娘, 新妇)," "eight characters of birth time (八字)," "the 7th day of the Lunar New Year (初七)," "dragon boat (龙船)" reflect the marital customs and festive traditions of the Minnan region. The words "pork tripe (猪肚)" and "the late-season rice harvested in October (尖仔)" are usually related to the local delicacies of the Minnan region. Furthermore, expressions like "sweetheart (心肝)," "sadness (伤心)," "heart (心头)," "miss (想着)" and "happiness (欢喜)" show the embedded emotions in the traditional MNRs. These words signify the strong cultural affinity at the core of the traditional MNR network. The semi-periphery nodes engage extensively with the core nodes and focus on similar thematic elements, including terms like "Chinese New Year (过年)," "Guanyin (观音)," "Buddha (佛主)" for describing the folkloric culture, terms like "castrated chicken (阉鸡)," "tofu (豆腐)," "salted vegetables (咸菜)" for the culinary traditions, and terms like "resentful (哀怨)" and "lonely (孤单)" for the expressed emotions. In addition, the semi-periphery nodes also convey family relationships, indicated by terms such as "mother (阿娘)," "brother (阿兄)," and "sister-in-law (阿嫂)." Moreover, the semi-periphery circle also includes terms like "winnowing basket (簸箕)," "broom (扫帚)," and "washing dishes (洗碗)" to describe the scenes of people working life. It is also noteworthy that terms related to children's education, such as "reading books (读册)," "instruction and guidance (教示)," and "studying the classics(读经)" are also included in the semi-periphery circle. The periphery nodes in the traditional MNR network present distinctive expressions with rich emotions and vivid life scenes.

The imagery of the modern MNR network differs from that of the traditional MNR network, demonstrating a shift towards a naturalistic focus in the modern NMR network. Specifically, the core circle of the modern MNR network is comprised of expressions such as "interesting (有趣)," "cute (可爱)," "abundant (满满)," and "joyful (欢喜)," which conveys joy and happiness. This collection also includes words associated with nature, specifically animals and plants, for instance, "cat (猫咪)," "dolphin (海豚)," "sunflower (向日葵)," and "leaves (树叶)," reflecting the focus of core nodes on expressing positive sentiments. In addition, the core node "Taiwan (台湾)" conveys cross-straits relation and political connotation in modern MNRs. In the modern MNR network, the node terms of semi-periphery and periphery weave together and are related to the quotidian and childhood experiences. They incorporate plant words like "dandelion (蒲公英)" and "pitcher plant (猪笼草)," activities such as "hide-and-seek (捉迷藏)," "taking a nap (睡午觉)," and visits to the "seaside (海边)," and fairy tales like "thunder god (雷公)," "thunder goddess (雷嬷)," further reflecting the modern MNR's emphasis on capturing the essence of children's daily life.

Table 5 Centrality rankings of top-20 node terms in the modern MNR network

Rank	Degree	Node	Weighted degree	Node	Betweenness centrality	Node	Eigenvector centrality	Node	Closeness centrality	Node
1	88	Funny (有趣)	200	Funny (有趣)	10.674	Funny (有趣)	1.000	Joyful (欢喜)	0.429	Joyful (欢喜)
2	73	Joyful (欢喜)	188	Joyful (欢喜)	8.018	Body (身体)	0.842	Funny (有趣)	0.422	Funny (有趣)
3	66	Body (身体)	164	Body (身体)	6.588	Joyful (欢喜)	0.755	Cute (可爱)	0.412	Body (身体)
4	64	Cute (可爱)	164	Cute (可爱)	5.251	Sweet potato (番薯)	0.638	Body (身体)	0.409	Cute (可爱)
5	57	Grandfather (阿公)	136	Grandfather (阿公)	5.211	Cute (可爱)	0.595	Abundant (满满)	0.408	Beauty (美丽)
6	49	Modal Particle —very (有够)	118	Interest (趣味)	4.274	Interest (趣味)	0.571	Beauty (美丽)	0.397	Abundant (满满)
7	47	Interest (趣味)	108	Abundant (满满)	4.252	Grandfather (阿公)	0.549	Grandfather (阿公)	0.397	Sweet potato (番薯)
8	45	Beauty (美丽)	108	Friend (朋友)	3.995	Modal Particle (有够)	0.471	Interest (趣味)	0.389	Sing (唱歌)
9	44	Abundant (满满)	106	Modal Particle —very (有够)	3.915	Beauty (美丽)	0.466	Sing (唱歌)	0.388	Taiwan (台湾)
10	44	Friend (朋友)	104	Taiwan (台湾)	3.79	Sing (唱歌)	0.447	Modal Particle —very (有够)	0.387	Modal Particle —very (有够)
11	43	Sing (唱歌)	102	Sweet potato (番薯)	3.525	Taiwan (台湾)	0.438	Sweet potato (番薯)	0.385	Grandfather (阿公)
12	43	Garden (花园)	102	Sing (唱歌)	3.328	**Uncle** (阿伯)	0.437	Friend (朋友)	0.381	Interest (趣味)
13	42	Sweet potato (番薯)	100	Beauty (美丽)	3.059	Friend (朋友)	0.426	Taiwan (台湾)	0.380	Eye (眼睛)
14	42	Taiwan (台湾)	100	Garden (花园)	2.859	**Watermelon** (西瓜)	0.413	Clean (干净)	0.378	Clean (干净)
15	42	Sun (太阳)	96	Sun (太阳)	2.801	Eye (眼睛)	0.410	**Smiling Mimi** (笑咪咪)	0.377	Friend (朋友)
16	37	Fragrant (香香)	84	Fragrant (香香)	2.715	Sun (太阳)	0.384	Garden (花园)	0.373	Garden (花园)
17	35	Trees (树木)	80	Eye (眼睛)	2.702	**Modal Particle —degree** (巴巴)	0.362	Eye (眼睛)	0.368	**Dolphin** (海豚)
18	34	Clean (干净)	76	Trees (树木)	2.573	**Object** (东西)	0.350	**Smiling Xixi** (笑嘻嘻)	0.361	**Cat** (猫咪)
19	33	Eye (眼睛)	74	Clean (干净)	2.321	Abundant (满满)	0.348	**Dolphin** (海豚)	0.353	Trees (树木)
20	33	Flower (花朵)	74	**Similar** (类像)	2.317	Garden (花园)	0.337	Sun (太阳)	0.351	Sun (太阳)

Words highlighted with bold font are new important words that are not included in the measure of node degree

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(a) Traditional MNRs

(b) Modern MNRs
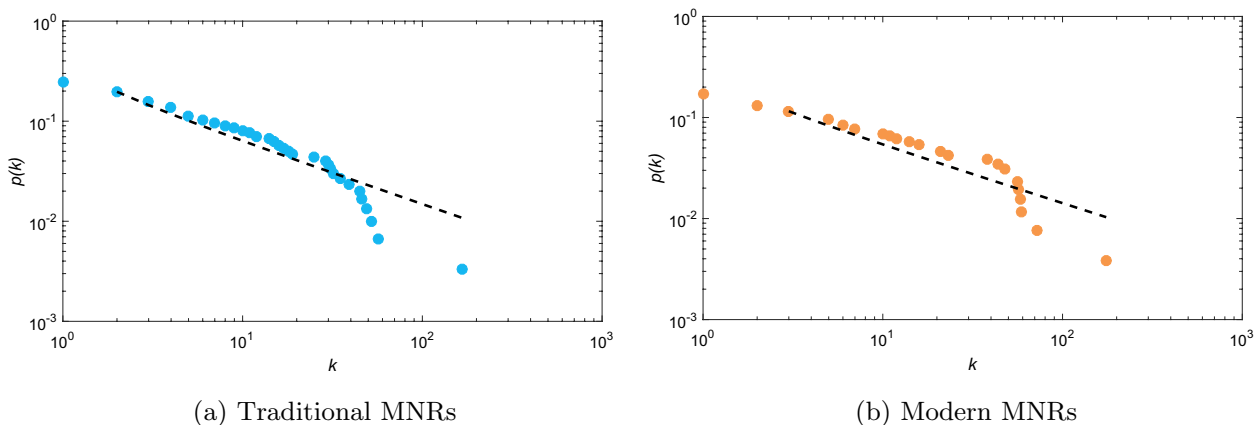
Fig. 3 The degree distribution of node

Table 6 Core-periphery analysis of MNR networks

Category	Correlation coefficient	Score range	Average core score	Core node percentage	semi-periphery node percentage	Periphery node percentage
Traditional MNR network	0.54	0-0.227	0.029	7.2%	46.3%	46.5%
Modern MNR network	0.68	0-0.377	0.021	8.2%	32.7%	59.1%

Analysis of imagery characteristics

Communities within both traditional and modern MNR networks are detected using the Louvain algorithm [61], as depicted in Fig. 5, where nodes of the same community are denoted by consistent coloring. In the traditional MNR network, five communities are detected with a modularity of 0.375, which indicates a well-defined community structure within the network when the modularity value exceeds 0.3. [67]. The themes of the five communities represent family relationships, folk culture, food culture, animal imagery, and emotional expression in the traditional MNR network. Conversely, the modern MNR network also presents five distinct communities with modularity of 0.582, representing family relationships, animal imagery, emotional expression, daily life, and natural scenery.

Family relationship

Most Minnan people place great emphasis on family kinship and fellow townsfolk sentiment. They usually consolidate kinship ties by tracing ancestral genealogies and constructing ancestral halls. The community marked with orange color in Fig. 5(a) signifies the family relationships in the Minnan region, and its imagery characteristic is described through words of immediate family relationship such as "bride (新娘)," "couple (夫妻)," "wife (老婆)," "husband (老公)," "mother (阿母)," "parents (爸

母)," and terms of extended family relationships, such as "grandma (阿嬤)," "eldest paternal aunt (大姑)," "eldest paternal uncle (大伯)," and "mother-in-law (亲姆)." Terms contained in those MNRs usually emphasize the significance of familial bonds and kinship relationships. For example, the nursery rhyme lyrics "Clapping song (拍手歌)" portray the tradition of gift-giving among family members: "... The eldest brother gives his sister a golden key as a present (大哥送妹金锁匙), the second brother gives his sister a golden chair (二哥送妹金交椅), the eldest sister-in-law presents her with a golden and silver phoenix hairpin (大嫂送姑金银拍凤钗), the second elder sister-in-law gifts her silk trousers and shoes (二嫂送姑骹帛饰裤鞋), the paternal grandparents present her with a golden ear hook (内公内嬷送孙金耳勾), the maternal grandparents send embroidered pillows to her (外公外嬷送孙绣枕头), and sisters of the same year give her a golden umbrella (同年姊妹送伊金凉伞)...". These traditional nursery rhymes underscore the significance of exchanging presents as a way to express care and convey best wishes within the family members.

Similarly, in the modern MNR network, nodes with orange color are used to represent the imagery of family relationships. This community includes words like "grandpa (阿公)," "parents (父母)," "uncle (叔叔)," and "paternal uncle (阿伯)" related to familial concepts. The well-known nursery rhyme "The sky is dark(天乌乌)"

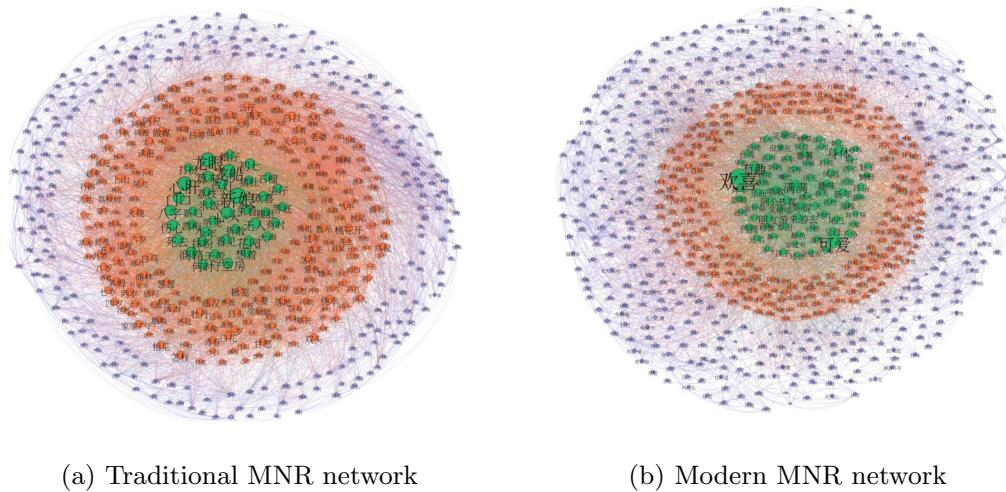(a) Traditional MNR network   (b) Modern MNR network

Fig. 4 Core-periphery structure of MNR networks

portrays the minor quarrels yet the intimate relationship between a grandfather and grandmother through lyrics: "... grandpa wants to cook food salty (阿公仔欲煮咸), grandma wants to stew a light soup (阿嬤欲煮汫), both quarreled and broke the pot (两个相拍弄破鼎)...". In addition, lyrics of the rhyme "Five paternal uncles (五个阿伯)" include: "...the eldest uncle teaches students (大伯在教书), the second elder uncle delivers letters (二伯在送信), the third elder uncle grows papayas (三伯种木瓜), the fourth elder uncle sells tofu pudding (四伯卖豆花), the fifth elder uncle sells corn (五伯卖玉米)...", which serves to teach children about kinship relationships within the family, as well as different types of professions and the different contributions each member makes to the society.

Folk culture

As shown in Fig. 5, the community, characterized by red-colored nodes, encapsulates the distinctive imagery of traditional folk culture in the Minnan region using terms such as "Goddess Mazu (妈祖)," "Buddha (佛祖)," "Guanyin (观音)," "dragon boat (龙船)," "the 7th day of the lunar month, often associated with particular festivals (初七)," "matchmaking (做媒)," and "lighting lamps (点灯)." Traditional nursery rhythms related to these terms usually convey the praying and blessing emotions and describe the related elements of the local culture. For example, the lyrics of a notable traditional nursery rhyme "Swallows Fly (燕仔飞)" go as follows: "swallows fly (燕仔飞), has the dragon boat come yet (龙船遘抑未)?... a wooden comb combs the bride's hair (岭兜一支柴梳好梳头), both the comb and hair are shiny (梳也光,箆也光)...." This nursery rhyme is widespread in the Minnan region, particularly in the Hua'an county of Zhangzhou, and it vividly

portrays scenes to reflect the marriage customs involving the terms "dragon boat" and "combing the bride's hair." Another famous rhyme "Xin Zheng Song (新正歌)" captures various New Year customs observed during the first lunar month. Its lyrics show the detailed practices of each day: "...eat seven types of vegetables on the 7th day of the Lunar New Year[3] (初七食七样), invite monks to conduct a blessing ceremony on the 8th day[4] (初八讨和尚), celebrate the Jade Emperor's birthday on the 9th day[5] (初九玉帝生), perform music pieces for praying auspiciousness on the 10th day[6] (初十人哆噔), and light lanterns to worship the ancestors and pray for their blessings on the 11th day[7](十一人点灯)...". By passing down these MNRs from

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[3] People will eat seven types of vegetables (brassica juncea, chard, celery, garlic, lactuca sativa, garlic chives, and Chinese broccoli) on the 7th day of the Lunar New Year, which is traditionally recognized as "Renri" - the human's birthday. It is a tradition to make a type of pancake with these seven vegetables. This practice embodies the wish for prosperity and good fortune.

[4] In order to pray for peace, auspiciousness, and welfare, people will invite monks to conduct blessing ceremonies.

[5] The ninth day of the Lunar New Year is the birthday of the Jade Emperor, a significant deity in Chinese tradition. On this day, families prepare elaborate banquets as offerings to honor the Jade Emperor, which serve as a means for the community to beseech blessings for the nation's tranquility and affluence, agricultural abundance, and overall harmony.

[6] On the tenth day of the first lunar month, the young people usually form percussion ensembles, performing a variety of rhythmic music. These performances are imbued with the intent to enhance the festive atmosphere, to pray for auspiciousness, and to ward off evil and avoid calamities.

[7] On the eleventh day of the first lunar month, it is a custom for eleven members of a family to light eleven lamps together. This tradition is to pay people's respect to their ancestors, and hope their forebears will provide their blessings and protection to the family. Such traditional practices are deeply rooted in the culture of honoring and remembering ancestors. Lighting lamps is a symbolic meant to guide the ancestors' spirits and to bring light and wisdom to the family.
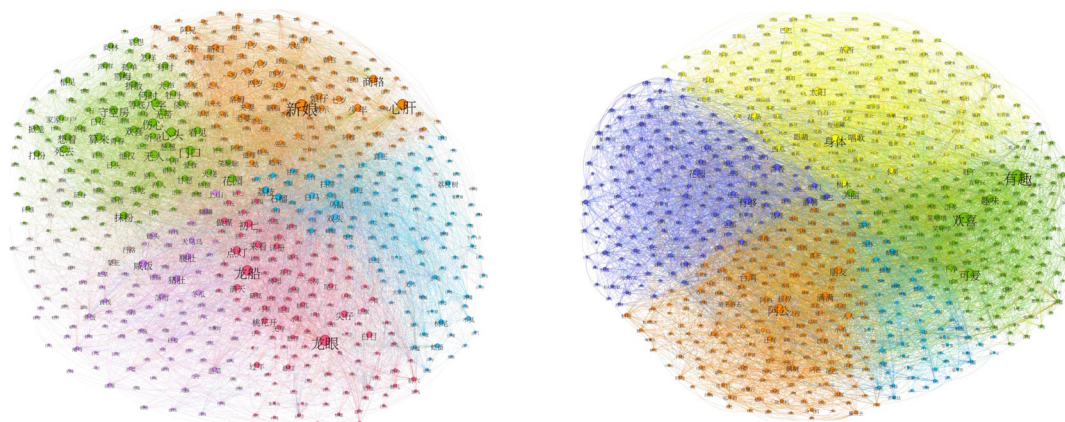
(a) Communities of the traditional MNR network

(b) Communities of the modern MNR network

Fig. 5 The community detection of MNR networks

generation to generation, people in the Minnan region can maintain their connection with their traditions, customs, and values. Therefore, these MNRs are not only important in portraying the rich folk culture of the Minnan region but are also crucial for preserving its heritage.

Food culture

Min cuisine, originating from Fujian food culture, stands as one of China's eight major culinary traditions, primarily encompassing dishes from the "Southern Fujian Golden Triangle" regions of Quanzhou, Xiamen, Zhangzhou, and Putian. It shares significant historical connections with the culinary practices of Taiwan, Hong Kong, Macau, and Southeast Asia regions. The genre of nodes within the purple-labeled community expresses the culinary culture prevalent in the Minnan region. Specifically, the terms "salty rice (咸饭)," "pork tripe (猪肚)," "pig chitterlings (猪肠)," " and "dried pickled radish (菜脯)" are related with distinct cuisine of Minnan region. Consider the lyrics from the nursery rhyme "Clams (涂鬼仔鲑)": "clams boiled Misua (涂鬼仔鲑炕汤煮面线)..., and the Misua makes me drool (害我鲞甲直流澜)." This nursery rhyme provides a vivid depiction of the preference for Misua and seafood among the inhabitants of the Minnan region. The nursery rhythm "Making rice cake (抉米糕)" describes the ingredients and process for making various kinds of snacks "...placing rice into a dorayaki mold to make rice cake (抉米糕, 引铜锣),... pork tripe cooked with lotus seeds (猪肚煮莲子), the lotus seeds are sweet (莲子甜是甜), preserved radish fried with green bean (菜脯炒豆青)..." Overall, these rhymes evidence the richness and diversity of the Minnan region's culinary delights, conveying not only people's love towards traditional food

but also reflecting the local residents' pride in their gastronomic culture.

Animal imagery

Nodes in the blue-color community focus on animal imagery with words such as "white horse (白马)," "frog (水鸡)," and "rat (鸟鼠)." Traditional MNRs exemplify this theme including "Young lambs (羊仔囝)" and "Egrets (白鹭鸶)." For instance, the lyrics of the nursery rhyme "Young lambs (羊仔囝)" go as follows: "young lambs (羊仔囝), bleating (咩咩吼), I lead the lamb to graze (牵伊去食草), I walk through my old granduncle's door (行遘老叔公的门骹口), a dog is tied at the door (拄着一只狗). The dog roars (狗仔吚吚吼), the lamb is frightened and runs away (羊仔蒮惊赶紧走)...", which depicts a child guiding a hungry lamb to graze while encountering a vicious dog. The egret is the regarded as a bird of good fortune in Minnan region. In the rhyme "Egrets (白鹭鸶)", people describe the spirit of enterprising and hard work of egrets through lyrics: " egrets are hurrying on their way (白鹭鸶,来赶路), crossing over mountains and streams (翻山岭，过溪河)..."

Moreover, in modern MNRs, terms such as "cat (猫咪)," "water buffalo (水牛)," "dolphin (海豚)," "crab (螃蟹)," and "dragonfly (蜻蜓)" are used to express the animal imagery. Examples such as "Earthworm (涂蚓)" and "The fight between ants and a centipede (狗蚁扛蜈蚣)" also incorporate animal imagery. The lyrics of "Earthworms (涂蚓)" are as follows: "Earthworms squiggle, squiggle in the round sand, the southern wind and moonlight love to sing songs, the soil is aerated, sweet potatoes and vegetables grow abundantly big (涂蚓涂蚓巴囵沙, 南风月光爱唱歌, 欢喜田园松化化, 番薯草菜碰碰大)." In addition,

the rhyme "The fight between ants and a centipede (狗蚁扛蜈蚣)" vividly describes the fight between ants and the centipede by lyrics "the ants are busily moving in a frantic swarm. Upon the road, they encounter a big centipede. Will the ants concede? all ants work together to fight with the big centipede (狗蚁搬家糖出动, 挨挨阵阵无闲工. 半路拄着大蜈蚣, 狗蚁汰讨甘愿放? 逐个和齐斗相共, 拼死拼活扛蜈蚣)…" To conclude, these rhymes reflect people's observation on animals. Through vivid descriptions, MNRs convey people's love and concern for nature and animals.

Emotional expression

Both traditional and modern MNRs serve as a medium for emotional expression in the Minnan region. In the traditional MNR network, the nodes in the green-colored community encompass a variety of emotions, including melancholy, happiness, farewell, and lovesickness. Typical traditional MNRs include "Sailing song (行船歌)" and "Good marriage (好良缘，结连理)." For instance, the "Sailing boat (行船歌)" lyrically illustrates Minnan people's feelings of wandering, loneliness, and homesickness: "…when the ship reaches the Cherished Islands (船到七洲洋), I start to miss my mother when gazing upon the ocean (看水想着娘). My tears fall and drift into the vast ocean (目屎流落去, 流落大海洋)… no one accompanies me (无人来做伴), my heart is broken (凄惨伤心肝)…" Alternatively, the rhyme "Good marriage (好良缘，结连理)" portrays the blessings bestowed upon newlyweds and expressing their aspirations for a harmonious and happy future together: "…the sweet soup tastes delicious (汤头甜好滋味), and brings a smile for the newlyweds after having the soup (食甲笑眯眯). The newlyweds' hearts are brimming with sweetness as if coated in honey (心里糖甘佫蜜甜)… this is a good marriage (好良缘，结连理), the newlyweds will have honey-sweet life (双双对对蜜蜜甜)…"

Unlike the above diverse emotions depicted in traditional MNRs, the modern MNR network's green-color community predominantly exhibits positive sentiments. This is indicated by the presence of word nodes such as "joy (欢喜)," "interesting (有趣)," "fun (趣味)," "smiling (笑眯眯)," and "giggling (笑嘻嘻)." In the rhymes "Go shopping (去逛街)" and "Singing cat (猫咪唱歌), the lyrics are respectively go as follows: "Going shopping is so fun, buying shirts, trousers, and bowls and chopsticks (去逛街,真有趣,买衫买裤买碗筷)…" and "the cat is so amusing, wanting to learn to sing do re mi, singing many times, but it always comes out as mi mi mi (猫咪猫咪真有趣,想要学唱 do re mi,唱来唱去,怎么都是 mi mi mi)…" Overall, the traditional MNRs incorporate diverse emotions of Minnan generations, and mainly describe the negative sentiments in the years of hardship. With China's

economic growth and modernization, the modern MNRs reflect societal changes and often aim to capture the joyful aspects of children's lives.

Daily life and natural scenery

As shown in Fig. 5b, the yellow-color community and dark blue-color community symbolize the daily life of children and the natural scenes in children's experiences, respectively, in the modern MNR network. The genres of many word nodes overlap in the two communities, i.e., a variety of words can be relevant to both daily life and natural environments. Such an overlap is caused by an interconnection between children's everyday experiences and their perception or interaction with nature. Words like "singing (唱歌)," hide-and-seek (捉迷藏)," " drawing (画画)," "body (身体)" and "washed up bright and clean (白白)" in the daily-life community reflect everyday activities and concepts in children's routines, possibly instilling values of personal hygiene, politeness, respect for others, and appreciation of the natural world.

Within the dark blue-colored community of the modern MNR network, terms such as "garden (花园)," "beach (海边)," "sea waves (海浪)," "landscape (风景)," and "rural (田园)" represent the theme of natural scenes. For example, the modern nursery rhyme "Xiamen Gulangyu (厦门鼓浪屿)" describes the UNESCO World Heritage Site Gulangyu island, which is known for its beautiful architecture, car-free environment, and rich cultural history. Specifically, the "Xiamen Gulangyu (厦门鼓浪屿)" lyrically depicts location of Gulangyu island with lines such as: "Gulangyu island is located opposite to Xiamen city at DaDeJi in the district of GangZiHou (厦门对面鼓浪屿, 大德记, 港仔后)." The narrative of this rhyme paints a serene island imagery by "the environment of Gulangyu island is very serene (岛上环境真清幽), piano melodies harmonizing with rolling sea waves (岛里琴声伴海涌), as if a beautiful garden filled with flowering trees (若像花园满花树)." It further vividly portrays coastal activities with phrases "men and women walk slowly by the seaside (男女海墘窣滇滇)" and "joyfully swimming and splashing in the sea (泅水诅诅抛鳞斗)." The rhyme further honors the historical figure General Chenggong Zheng (郑成功), a Southern Ming loyalist who defied the Qing's conquest in the 17th century, in the lines: " There are many stories of renowned people (名人事迹故事多)' and " The hero Chenggong Zheng is one of them (早年英雄郑成功)." Overall, these modern MNRs serve as a resource to express and maintain the distinctive natural and cultural landscapes of the Minnan region.

Summary of the imagery analysis

Based on the imagery analysis in Sects. 6.1, 6.2, 6.3, 6.4, 6.5 and6.6, both traditional and modern MNRs exhibit

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similarities and differences in emphasis due to the inherent characteristics of nursery rhymes, the cultural background of the Minnan region, and the economic development of different eras. The shared emphasis on family relationships in both traditional and modern MNRs, showcasing a common theme across generations of MNRs, originates from the deeply rooted clan culture in the Minnan region [68, 69]. The emotion expression and animals in nursery rhymes are important elements that allow children to express their feelings and unleash their creativity [70–72]. The shared emotional expression and animal imagery in both traditional and modern MNRs underscore their significance in nurturing children's cognitive development. Despite the same emphasis on family, animal, and emotional imagery as modern MNRs, traditional MNRs stand out for their emphasis on food and folk culture imagery, which can be attributed to the socioeconomic conditions of China in the past. In times past, when food resources were scarce, festivals were crucial occasions for enjoying a variety of otherwise unavailable dishes [73, 74]. Consequently, food became closely intertwined with folk culture and traditions. These elements are typically highlighted in traditional MNRs as symbols of abundance and prosperity. Conversely, modern MNRs have shifted focus towards daily life and natural scenery to describe children's growing-up experiences, with a diminishing emphasis on food elements due to economic progress and improved living standards. Furthermore, the influence of globalization has reduced the depiction of cultures and festivals in MNRs as people are increasingly exposed to international holidays [75, 76].

It is noticeable that the main difference between the classified imagery characteristics in Sect. 6.1, 6.2, 6.3, 6.4, 6.5 and 6.6 and the categories in Table 1 lies in their derivation method and analysis perspective. Specifically, the categorization in Table 1 utilizes a qualitative, manual process carried out by domain experts. These experts systematically review a wide range of historical and literary data sources to summarize the content types by interpreting themes, scenarios, functions, and values embedded in the nursery rhymes. This approach provides insights from a rhyme-level perspective, meaning that the analysis considers the overall content of each nursery rhyme as a whole unit. In contrast, the imagery analysis employs a data-driven method focusing on detecting community patterns within the MNR networks. The community-detection method is conducted from a word-level perspective focusing on individual words or phrases within the rhymes instead of their overall thematic content. This method may uncover high-dimensional cultural connotations and provide novel insights compared with the manual analysis. The objectivity inherent in this approach helps mitigate human bias, potentially leading to a more reliable and replicable analysis.

Discussion
Characteristics of MNRs

The original style of MNRs is highly related with the traditional oral rhyming verse "four-line ballad in Minnan dialect(四句念)" in the folklore of Minnan. The "four-line ballad in Minnan dialect(四句念)", also known as "Four-Line Verse", comprises four lines of equal length, each containing either five or seven words [77]. It is renowned for its brevity, as well as its lively and witty language delivered in a rhyming pattern. This art form enjoys widespread appreciation across various demographics and professions within the region due to its rhyme in composition, simplicity, and ease of transmission. It is evident that lyrics in both traditional and modern MNRs frequently utilize rhyme. Sometimes, lyrical semantics are sacrificed to uphold rhyming patterns. The "Four-Line Verse" have evolved into longer stanzas or even full-length ballads to accommodate a more excellent range of content and expressive needs. For example, the "The Chinese zodiac (十二生肖歌)" includes about 400 words [78] to teach children the knowledge of zodiac animals.

The MNRs employ a rich, vibrant, and humorous lexicon, as well as idioms (including colloquial expressions, idiomatic phrases, proverbs, and riddles) that are deeply rooted in these nursery rhymes. Many words in Minnan dialect are inherited from classical Chinese, which have become obsolete or less commonly used in Mandarin or other Chinese dialects. However, they are widely used in the traditional MNRs. For example, the term "好空" is referred to as "rich" in Minnan dialect, a connotation seldom found in Mandarin or other dialects. The term "大家" can refer "mother-in-law" in Minnan region, while it means "we" in Mandarin. Additionally, the MNRs usually use the personifications and humorous expressions to depict people, animals or things. For instance, one nursery rhyme depict insects with lyrics "The louse wants to marry a flea, so she asks a psyllidae to be the matchmaker (虱母要嫁家蚤翁,去叫木虱做媒人)..." Moreover, to enhance the enjoyment of nursery rhymes, MNRs incorporate literary devices such as exaggerations, parallelisms, and onomatopoeia.

A salient feature of MNRs is their collective creation, which refers the difficulty to attribute most MNRs to an individual author. As a form of oral literature, MNRs originate from spontaneous reactions to everyday occurrences. An individual may instinctively recite a verse, which then becomes subject to alterations and enhancements by others. Consequently, the finished composition typically emerges from the combined creative input of multiple contributors. With regard to their

transmissional evolution, MNRs often evolve into different versions with the same theme. Although distinct versions may exhibit minor content differences, such as the insertion or omission of specific words or phrases. For example, two versions of the nursery rhyme "Bright Moon (月娘月光光)" employ metaphorical expressions and a child-like lexicon to depict the moon. The lyrics of the first version are: "Bright moonlight, rising up in the center of the fields. Fond of three-colored candy, fond of sleeping on the beautiful bed. (月娘月光光,起厝田中央。爱食三色糖，爱眠水眠床。)" The second version contains similar thematic content: "Bright moonlight, rising up in the center of the fields. River snails transform into water jars, and paper boxes transform into beds (月娘月光光， 起厝田中央，田螺做水缸，纸盒做眠床。)" In contrast, the lyrics of another variant differ considerably from the above two nursery rhymes. This version portrays the "Bright Moon (月娘月光光)" as follows: "Bright moonlight, an old man in the garden plans to cultivate new crops. Yet, his efforts are met with frustration. The onions fail to sprout, the tea plants remain flowerless, and the melons develop without seeds. This series of agricultural endeavors leaves the old man exasperated to the point of despair (月娘月光光，老公仔伫菜园，菜园掘松松，老公仔欲种葱，葱无芽。欲种茶，茶无花。欲种瓜，瓜无子。老公仔气甲欲死)."

Values of MNRs

The MNRs encompass a wide range of topics, including societal issues, historical figures and events, local folklore, and natural elements, reflecting various aspects of life and culture of the Minnan region. These MNRs will foster children's social interaction, cooperation, and teamwork by participating in group recitations or singing sessions. The rhythmic patterns, repetition, and melodic tones of MNRs contribute to the language development of children. Therefore, MNRs serve as a significant education value for children's education from an early age.

In addition, by incorporating elements of local dialects, societal norms, folklore, and historical events, MNRs serve as a living repository of cultural knowledge. As children learn and pass on these rhymes, they create connections with their cultural knowledge. So, MNRs also serve as an invaluable tool for the preservation of Minnan cultural heritage because cultural knowledge is reinforced and inherited through these interactions.

The popularity of MNRs is not only within the Minnan and Taiwanese regions but also extends to Chaoshan and Leizhou in Guangdong province, Hainan Island, Pingyang and Yuhuan in Zhejiang province. Moreover, the dissemination of MNRs transcends geographical boundaries into Southeast Asian regions owing to people's migration. The shared elements, such as proverbs, stories, and values, that are found within the MNRs create a sense of belonging among Minnan-speaking communities. For communities dispersed across various regions, these shared cultural practices serve as an essential link connecting the Minnan people at home and abroad, significantly contributing to the cultural identity and cohesion among its members.

Limitation

Given the long history of Minnan nursery rhymes, the data gathered in this study remains relatively sparse. It is necessary to conduct more comprehensive and in-depth fieldwork to collect MNRs.

As the lyrics of MNRs comprise numerous non-Mandarin characters and Minnan proverbs, the traditional word segmentation method employed in this study may still result in inaccurate outcomes. It is noticeable that the obtained segmentation may potentially influence the structure of MNR networks. Consequently, it is essential to design a more sophisticated approach for extracting and analyzing the semantic meaning of lyrics while also considering rhyme patterns. The tailored segmentation approach would align with the unique characteristics of the Minnan language, ensuring further precise analysis and interpretation.

In this study, we employ the conventional approach of community detection to analyze the MNR network. It is worth highlighting that the integration of advanced techniques for community detection, such as machine learning and graph neural network-driven methods, may potentially unveil novel insights and provide a deeper understanding of the symbolic imagery embedded within MNRs.

Conclusion and future research

This study aims to examine the unique characteristics and patterns of Minnan nursery rhymes through text mining methods, including text segmentation, TF-IDF, and complex network theory. Specifically, we first collected traditional MNRs edited by experts and modern MNRs sourced from the internet. Subsequently, we preprocessed and segmented the lyrics using our designed Chinese-Minnan dictionary. We further extracted vital terms using the TF-IDF method and constructed separate networks for traditional and modern MNRs, with the terms serving as nodes and the co-occurrence relationships forming the links.

The analysis of lyrical terms revealed that a limited number of key terms had a high frequency of occurrence and conveyed specific emotions in both traditional and modern MNRs. Additionally, we employed network indicators to evaluate the structure of the constructed MNR networks. The findings demonstrated

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that both the traditional and modern MNR networks exhibited overall sparsity, internal cohesion, and strong community characteristics. When examining node centrality, the highly central nodes in the traditional MNR network reflected unique elements associated with idyllic depictions of life, folks, values, and distinctive cultural themes in the Minnan region. Conversely, important nodes in the modern MNR network are primarily related to positive emotional words. Our further investigation included analyzing the degree distribution of the traditional and modern MNR networks, and both of them followed a power-law distribution. We also explored the core-periphery structure of the MNR networks. The core terms within the traditional MNR network represent folkloric and food culture, as well as emotional expressions specific to the Minnan region. In contrast, the core of the modern MNR network did not relate to Minnan culture and was primarily focused on conveying joyful emotions among children. Lastly, we conducted community detection on both the traditional and modern MNR networks, resulting in five communities for each. In the traditional MNR network, these communities represent family relationships, folk culture, food culture, animal imagery, and emotional expressions, aligning with the values and beliefs of the Minnan people in historical periods. Conversely, the modern MNR network is also comprised of five communities, but with differing imagery symbols, including family relationships, animal imagery, emotional expressions, daily life, and natural scenery. These changes could be attributed to shifts in people's lifestyles, economic development, and the impact of cultural globalization.

The exploration of Minnan nursery rhymes through the complex network analysis unveiled intriguing research directions for future work. We plan to compare the characteristics of Minnan nursery rhymes with nursery rhymes from other regions in our future research. Such a comparative study can help deepen our understanding of the diversity and uniqueness of nursery rhymes across different regions, contributing to the preservation of cultural heritage. Moreover, constructing a large-scale and comprehensive multimodal knowledge graph to encompass MNRs will be a promising direction for future research. This research has the potential to address hidden knowledge embedded in MNRs and promote interdisciplinary research and cross-cultural understanding in the fields of linguistics, cultural studies, and digital humanities. Another interesting direction for future research is the impact of Minnan nursery rhymes on children's development and language acquisition. This study may involve empirical research, such as conducting experiments or surveys, to examine how exposure to Minnan nursery rhymes influences aspects such as language proficiency, cognitive development, and cultural awareness of children.

Author contributions
Conceptualization: WH and LS; Methodology: WH and ZL; Validation: HZ, CZ, YW, SY and TX; Result analysis: WH, ZL, YW and TX; Investigation: HZ, CZ, TX and SY; Data collection and labeling: HZ and CZ; Data curation: HZ, CZ, ZL and TX; Writing-original draft preparation: WH and ZL; Writing-review and editing: YW, LB and TX; Visualization: ZL and TX; Reviewing, language and editing: YW, LB and SY Project administration: Shunxing Li; Funding acquisition: WH and SY. All authors have read and agreed to the published version of the manuscript.

Availability of data and materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

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References
1. Blake J. Unesco's 2003 convention on intangible cultural heritage: the implications of community involvement. Milton Park: Routledge; 2008. p. 45–50.
2. United Nations Educational S., Organization C. human intangible cultural heritage representative list. 2023. https://whc.unesco.org/zh/list/. Accessed 11 Oct 2023.
3. Wang M. A new perspective on the inheritance of minnan nursery rhymes from the perspective of intangible cultural heritage. Conten Lit Art. 2015;6:204–6.
4. Xiamen.chinadaily.com.cn: Minnan nursery rhymes. 2019. https://xiamen.chinadaily.com.cn/2019-05/06/c_346992.html. Accessed 11 Oct 2023.
5. White C. Waves of influence across the south seas: mutual support between protestants in minnan and southeast asia. Ching Feng. 2012;11(1):29–54.

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6.   Hui L. The multicultural value of minnan nursery rhymes and their contemporary inheritance. Fujian Tribune (Human Soc Sci). 2012;12:125–8.

7.   Yaling L. A brief discussion on the application of minnan nursery rhymes in kindergarten games. Asia-Pacific Educ. 2019;4(4):48–9.

8.   Zhenwen L. Inheritance and protection strategies of minnan language-taking quanzhou primary school as a sample. North Lit. 2019;1(17):250–2.

9.   Fang C. The distinction among tongyao, erge and chenyao and the characteristics of minnan tongyao. J Jimei Univ (Philos Soc Sci). 2022;25(1):6.

10. Huan L. Investigation and research on the status quo of campus inheritance of minnan nursery rhymes– taking three primary schools in quanzhou city as examples. Master's thesis, Quanzhou Normal University; 2023.

11. Network CICH. List of representative items of national intangible cultural heritage. 2008. https://www.ihchina.cn/project.html. Accessed 20 Dec 2023

12. Zhang Y, Han M, Chen W. The strategy of digital scenic area planning from the perspective of intangible cultural heritage protection. Eurasip J Image Video Process. 2018;2018(1):1–11.

13. Lv L, Wu J, Lv H. A community discovery algorithm for complex networks. J Phys: Conf Seri. 2020;1533:032076.

14. Ebrahimi AS, Yavari E, Khatibi T. Novel methods for creating an earthquake complex network using a declustered catalog. Chaos, Solitons Fract. 2021;147: 110945.

15. Li Y, Guo J, Zhao L, Chen Y, Wang C, Wang C, Li J. Spatial evolution path of gulangyu island historical international community: from the perspective of actor-network theory. Herit Sci. 2021;9:1–17.

16. Liu J, Fang Y, Chi Y. Evolution of innovation networks in industrial clusters and multidimensional proximity: a case of chinese cultural clusters. Heliyon. 2022;8(10):e10805.

17. Li J, Zhang C, Tan H, Li C. Complex networks of characters in fictional novels. In: 2019 IEEE/ACIS 18th international conference on computer and information science (ICIS), IEEE 2019. pp. 417–420.

18. Li Z, Ma L, He J. Study on character relationship modeling based on complex network –take a dream of red mansions as an example. Mod Inf Technol. 2021;5(3):5.

19. Boccaletti S, Latora V, Moreno Y, Chavez M, Hwang D-U. Complex networks: structure and dynamics. Phys Rep. 2006;424(4–5):175–308.

20. Barabási A-L, Loscalzo J, Silverman EK. Network medicine: complex systems in human disease and therapeutics. Harvard University Press; 2017.

21. Sporns O. Networks of the brain. Cambridge: MIT press; 2016.

22. Labatut V. Complex network analysis of a graphic novel: the case of the bande dessinée thorgal. Adv Complex Syst. 2022;25(05n06):2240003.

23. Bost X, Gueye S, Labatut V, Larson M, Linarès G, Malinas D, Roth R. Remembering winter was coming: character-oriented video summaries of tv series. Multimed Tools Appl. 2019;78:35373–99.

24. Weng C-Y, Chu W-T, Wu J-L. Rolenet: movie analysis from the perspective of social networks. IEEE Trans Multimed. 2009;11(2):256–71.

25. Buk S, Rovenchak A. Stanza-based networks for poetic texts: a pilot study. Glottotheory. 2023;14(1):11–32.

26. Roxas-Villanueva RM, Nambatac MK, Tapang G. Characterizing english poetic style using complex networks. Int J Mod Phys C. 2012;23(02):1250009.

27. Smolla M, Akçay E. Cultural selection shapes network structure. Sci Adv. 2019;5(8):0609.

28. Xu Y. Entering into minnan nursery rhymes and feeling the charm of art. Contemp Fam Educ. 2020;26:55–6.

29. Huang X. Research on the design of conceptual picture books for minnan nursery rhymes - starting from "roasted meat dumplings". J Kaifeng Vocat Coll Cult. 2022;42:121–5.

30. Wang M. An analysis of the contemporary cultural and educational value of minnan nursery rhymes. Conten Lit Art. 2017;11:205–8.

31. Chen F. The protection and inheritance of minnan nursery rhymes from the perspective of chen fang's same origin in fujian and taiwan. J Jimei Univ (Philos Soc Sci). 2016;19:9–13.

32. Wang L. On the inheritance and development of minnan nursery rhymes. Olk Art Lit. 2011;04:98–9.

33. Shunmei L, Zahari ZA. The design and development of cultural and creative products from the perspective of digital media-taking intangible cultural heritage of nursery rhymes in minnan dialect as an example. J Posit Sch Psychol. 2022;6(8):287–98.

34. Zhang J. Exploring the integration of minnan nursery rhymes into low stage music classes in primary schools. J North Music. 2020;08:157–8.

35. Xie J. Singing local sounds to evoke local sentiment - on the practice and reflection of integrating minnan nursery rhymes into primary school music teaching. J North Music. 2017;37:105.

36. Lin X. The application and innovative strategies of minnan nursery rhymes in kindergarten teaching activities. Theory Pract Innov Entrep. 2019;2:41–2.

37. Wang L, Zhang X. The lively inheritance and media enhancement of minnan nursery rhymes from the perspective of sociocultural psychology. J Fuzhou Univ (Philos Soc Sci). 2021;35(04):107–12.

38. Chen C. Research on the design of children's picture books based on mobile augmented reality technology - taking minnan nursery rhyme picture books as an example. View on Publishing. 2021;83–85. https://doi.org/10.16491/j.cnki.cn45-1216/g2.2021.04.025.

39. Danhong Z. Music teaching practice based on the five characteristics of minnan nursery rhymes. J Fujian Inst Educ. 2020;21:104–5.

40. Zhou C. 500 nursery rhymes from Southern Fujian. Fuzhou: Strait Publishing and Distribution Group; 2003.

41. Jiang Y. Zhangtai Minnan dialect nursery rhymes. Xiamen: Xiamen University Press; 2011.

42. Zhou C, Zhou Q. Selections of Singaporean Hokkien folk songs. Xiamen: Xiamen University Press; 2003.

43. Hoemann K, Xu F, Barrett LF. Emotion words, emotion concepts, and emotional development in children: a constructionist hypothesis. Dev Psychol. 2019;55(9):1830–49.

44. Gennari SP, MacDonald MC, Postle BR, Seidenberg MS. Context-dependent interpretation of words: evidence for interactive neural processes. Neuroimage. 2007;35(3):1278–86.

45. Yu Y, Zhou B, Chen L, Gao T, Liu J. Identifying important nodes in complex networks based on node propagation entropy. Entropy. 2022;24(2):275.

46. Shannon CE. A mathematical theory of communication. Bell Syst Tech J. 1948;27(3):379–423.

47. Qiu H, Zheng Q, Msahli M, Memmi G, Qiu M, Lu J. Topological graph convolutional network-based urban traffic flow and density prediction. IEEE Trans Intell Transp Syst. 2020;22(7):4560–9.

48. You J, Gomes-Selman JM, Ying R, Leskovec J. Identity-aware graph neural networks. Proc AAAI Conf Artif Intell. 2021;35:10737–45.

49. You J, Ying Z, Leskovec J. Design space for graph neural networks. Adv Neural Inf Process Syst. 2020;33:17009–21.

50. Yu Z, Chen L, Tong H, Chen L, Zhang T, Li L, Yuan L, Xiao J, Wu R, Bai L, et al. Spatial correlations of land-use carbon emissions in the yangtze river delta region: a perspective from social network analysis. Ecol Ind. 2022;142: 109147.

51. Zhang Q, Shuai B, Lü M. A novel method to identify influential nodes in complex networks based on gravity centrality. Inf Sci. 2022;618:98–117.

52. Rodrigues FA. Network centrality: an introduction. A mathematical modeling approach from nonlinear dynamics to complex systems. Berlin: Springer; 2019. p. 177–96.

53. Zhong S, Zhang H, Deng Y. Identification of influential nodes in complex networks: a local degree dimension approach. Inf Sci. 2022;610:994–1009.

54. Wikipedia: Eigenvector centrality. 2024. https://en.wikipedia.org/wiki/Eigenvector_centrality. Accessed 2 Jan 2024.

55. Ma H, Liu J, Zhao X, Zhang B. A study of highway logistics transportation network structure in China: from the perspective of complex network. J Data, Inf Manag. 2022;4(2):89–105.

56. Ding R, Ujang N, Hamid HB, Manan MSA, Li R, Albadareen SSM, Nochian A, Wu J. Application of complex networks theory in urban traffic network researches. Netw Spat Econ. 2019;19:1281–317.

57. Pastén D, Czechowski Z, Toledo B. Time series analysis in complex networks. Chaos: Interdiscip J Nonlinear Sci. 2018. https://doi.org/10.1063/1.5023923.

58. Furse CM, Kafal M, Razzaghi R, Shin Y-J. Fault diagnosis for electrical systems and power networks: a review. IEEE Sens J. 2020;21(2):888–906.

59. Bonfanti A, Kaplan JL, Charras G, Kabla A. Fractional viscoelastic models for power-law materials. Soft Matter. 2020;16(26):6002–20.

60. Borgatti SP, Everett MG. Models of core/periphery structures. Soc Netw. 2000;21(4):375–95.

61. Que X, Checconi F, Petrini F, Gunnels JA. Scalable community detection with the louvain algorithm. In: 2015 IEEE international parallel and distributed processing symposium, IEEE. 2015;28–37.

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62. Newman M. Networks: an introduction. Oxford: Oxford University Press; 2010.
63. Ma Y, Xie Z, Li G, Ma K, Huang Z, Qiu Q, Liu H. Text visualization for geological hazard documents via text mining and natural language processing. Earth Science Informatics, 2022;1–16.
64. Clauset A, Shalizi CR, Newman ME. Power-law distributions in empirical data. SIAM Rev. 2009;51(4):661–703.
65. Virkar Y, Clauset A. Power-law distributions in binned empirical data. Dissertations and Theses Gradworks, 2012.
66. Maydeu-Olivares A. Maximum likelihood estimation of structural equation models for continuous data: standard errors and goodness of fit. Struct Equ Modeling. 2017;24(3):383–94.
67. Blondel VD, Guillaume J-L, Lambiotte R, Lefebvre E. Fast unfolding of communities in large networks. J Stat Mech Theory Exp. 2008;2008(10):10008.
68. Tang Z. Changes with Chinese characteristics: rural clan culture, clan communities, and Kinship relations during urbanization. Singapore: Springer; 2017. p. 161–98. https://doi.org/10.1007/978-981-10-4831-9_10.
69. Yang X. Ritual and gender role in a sanyang village patriarchal clan, fujian. Praxis, Folks' Beliefs, Rit Explor Anthropol Relig. 2022. https://doi.org/10.9734/bpi/mono/978-93-5547-925-9/CH6.
70. Mullen G. More than words: using nursery rhymes and songs to support domains of child development. J Child Stud. 2017;42:42–53.
71. Ayres B. Animals and Their Children in Victorian Culture. Milton Park: Routledge; 2019. p. 12–30.
72. Pullinger D. Nursery rhymes: poetry, language, and the body. Milton Park: Routledge; 2017. p. 156–73.
73. Newman J. Food culture in China. London: Bloomsbury Publishing; 2004.
74. Montanari M. Food is culture. Columbia: Columbia University Press; 2006.
75. Tomlinson J. Globalization and culture. Chicago: University of Chicago Press; 1999.
76. Lum C-H. Home musical environment of children in singapore: on globalization, technology, and media. J Res Music Educ. 2008;56(2):101–17.
77. Zhuang X. "Reciting four sentences" in fujian and taiwan wedding customs and its cultural implications. Root Explor. 2014;5:57–61.
78. Zhu J, Xu P. The Chinese zodiac. Child Music. 2004;12:9–9.

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