



Social Media Analytics of User Evaluation for Innovative Digital Cultural and Creative Products: Experiences regarding Dunhuang Cultural Heritage

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Social media platforms play an increasingly important role in cultural communication as society develops, attracting promotions and discussions about digital cultural and creative products (CACPs). This research investigates the cultural collaboration between Tencent and Dunhuang Research Academy (Dunhuang Academy) and analyzes user evaluation of integrating cultural heritage education into CACPs. We obtained data through Weibo and compared user evaluations and semantic social network analysis of digital CACPs, including interactive products, games, and music. Results indicated that users were more interested in landscapes, dubbing, and user-generated content (UGC) for interactive products, character versions, posters and skills for games, and singers and songs for concerts. Semantic social network analysis was also used to explore the Dunhuang CACP Circle. Scant studies evaluate the usefulness of integrating cultural heritage into different digital CACPs, especially in Asia. Our suggestions help promoters understand user needs for digital CACPs and better user experience and value.

CCS Concepts: • Applied computing → Education; Interactive learning environments; Law, social and behavioral sciences; Sociology;

Additional Key Words and Phrases: User evaluation, cultural heritage, digital cultural and creative products, Neo-culture creativity, Web crawling, Weibo declaration

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1 INTRODUCTION

The dissemination of cultural heritage is related to awareness of the values enshrined in cultural heritage [15, 69, 79]. With the rise of digital mobile devices, cultural heritage institutions are exploring the promotion of cultural heritage more attractively through electronic devices [7, 18, 59, 68]. Some researchers have recently explored ways to promote cultural heritage through virtual reality, panorama digital libraries, and immersive

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digital cultural heritage installations [4, 17, 29, 39, 55, 65], their effects, and user evaluation [22]. Some researchers have also studied the interconnections between cultural heritage and video games [9, 10, 43]. However, few researchers have studied the effectiveness and user evaluation of learning about historical and cultural heritage by comparing interactive experience programs, music, and video games, i.e., comparing the effectiveness of cultural heritage communication through user evaluations between different digital **cultural and creative products (CACPs)**. Therefore, this study will explore this part based on a collaborative program between the Dunhuang Academy and Tencent.

Dunhuang Cultural Heritage, also known as the Mogao Grottoes Heritage, is located southeast of the Dunhuang Oasis, Gansu Province, China. It was inscribed on the **UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage List** in December 1987 and is a famous World Cultural Heritage site. Dunhuang Cultural Heritage has a rich collection of murals, sculptures, and scriptures, which possess unmatched historical and cultural significance in China and beyond [52]. The Dunhuang Academy manages the largest number of world cultural heritage sites in China, focusing mainly on Dunhuang culture and other heritage sites. The Tencent Group is a global internet and technology company based in China. In the past few years, Tencent has utilized its technological expertise to contribute to the sustainable preservation of cultural heritage worldwide. Since 2017, Tencent has partnered with the Dunhuang Academy to digitally preserve, display, and disseminate valuable cultural artifacts from Dunhuang and seamlessly integrate its innovative products with the rich cultural heritage of Dunhuang. The Dunhuang Academy and Tencent signed a cooperation agreement on December 29, 2017, to launch the “Digital Supporters” program. This innovative program launched the “King of Glory” video game¹ visual effects package featuring the Dunhuang theme, “Dunhuang E-Tour,” as WeChat and QQ² interactive experience mini-programs,³ the concert “Ancient Music Rebirth,” and so forth.

Over the past 4 years, more than 250 million people have engaged in online activities related to these entertainment activities. The Weibo platform is considered one of China’s most influential and prominent social media sources, comparable to X (formerly known as Twitter). The official Weibo Web site reported that nearly 80% of its users were from the 1990s and 2000s in 2020, and the number of monthly active users was 582 million in June 2022. The extensive user base and abundance of official accounts on Weibo make it an ideal platform for studying the promotion of heritage. As a result of Weibo’s real-time updates and trending topics, researchers could identify the latest trends and public sentiment regarding heritage topics in China and gain a comprehensive understanding of Chinese public opinions regarding cultural heritage products. Thus, this research uses Dunhuang cultural heritage as the case for social media analytics [44] on Weibo to evaluate user perceptions of cultural heritage in innovative digital products among Chinese Weibo users. These products encompass interactive experience programs, music, video games, and so forth. This research helps demonstrate the effectiveness of innovative cultural heritage communication, promotion, and recommendations for digital CACPs and services.

As for methodological contribution, this research uses text mining to scrape the relevant reviews of Weibo and analyze user evaluations to reveal the effectiveness of the innovative application of Dunhuang heritage cultural elements promoted in CACPs. Particularly, to explore the product elements of CACPs that can generate users’ sustained positive attention and deep cultural experience from multiple user perspectives, as well as the user groups that are likely to promote these innovative products, the following **Research Questions (RQs)** guide this study:

¹King of Glory is a multiplayer online competitive mobile game developed by Tencent.

²WeChat and QQ applications are Chinese instant messaging and social networking mobile services developed by Tencent.

³Mini-programs are “sub-applications” built into the WeChat and QQ platforms. The experience is the same as native apps without having to download them from the app store.

Table 1. Research on Digital CACPs

Author	Methods	Findings
Park [50]	Text mining	The mode of the cultural and creative industry in China is moving towards the humanization of experience.
Wiltshier and Clarke [70]	Case study	The technology is extremely impressive for virtual cultural tourism experiences, but it is difficult to engineer all the senses.
Barwick et al. [7]	Case study	Attract users' attention by combining physical and digital collections in the game.
Zou et al. [83]	Case study	Compared to previous media methods, VR (virtual reality) animation technology is more widely distributed and promoted, leaving a deeper impression on users.
Dai [13]	Quantitative analysis	In the digitization process of CACPs, color matching and interactive experience can improve user satisfaction. In addition, the design process should pay attention to the aesthetic visual experience of products, creative cultural stories, and humanistic care.
Luiro et al. [40]	Case study	The game design should balance historical accuracy and an interesting storyline considering the target user group.

RQ1: From innovative CACPs with Dunhuang cultural elements, what themes and designs (e.g., video game visual effect packages, video game story contents, and stage scenes in concerts) catch user attention?

RQ2: What kind of innovative CACPs can give users a deeper experience of Dunhuang culture?

RQ3: What factors can arouse users' continuance of positive views on Dunhuang cultural heritage when using innovative CACPs?

RQ4: What kind of circles on Weibo have better potential to promote innovative Dunhuang CACPs?

2 LITERATURE REVIEW

2.1 Development Status and Value of Digital CACPs

Table 1 summarizes some case studies on digital CACPs, showing that the current cultural and creative industries focus on combining physical entities with digital products and prefer humanized design and visual experience in innovative interactive experience products. Currently, most research on digital CACPs focuses on virtual reality devices, while relatively few studies focus on mobile applications for CACPs and comparing digital CACPs. Thus, this research fills the gap by analyzing different CACPs on mobile applications, especially with a social media analytics approach.

In mobile applications, users prefer to explore the experience effect of products [24]. Tynan and McKechnie [67] outlined the process of user value experience comprising three stages relevant to experiences in innovative digital CACPs: the learning before the product experience, the experience of value sources, and the result after the experience. The first phase is the pre-experience, which is about imagining, searching, and planning activities. It is the process of anticipating and planning to use a product after users know about it. The second phase focuses on the value sources of experience, including sensory, emotional, functional, informational, and novelty. This phase focuses on the experience and feelings associated with using the product. The third phase, post-experience, concerns the outcomes of the experience, such as enjoyment, entertainment, learning skills, nostalgia, and fantasizing. This phase covers the user's memories and knowledge acquisition of the product after using it, and this is a crucial stage for users to keep using the product. The pre-experience phase is often handled by the

advocacy team of CACPs to disseminate information to potential users before the product launches. After learning about the promotion, users will have relevant experience and discuss the effect and recall experience, reflecting the value experience process of the second and third stages. It is essential to run CACPs through all phases of the model to let users immerse themselves in the experience to gain a deeper understanding of the cultural values and expectations of cultural heritage. Therefore, this research analyzed the following data results based on this framework, and user value experience is also referred to as user experience.

2.2 Clustering of Social Media Information

Text clustering is a popular and effective way to automatically process and organize large amounts of text [2, 32, 35, 66]. The k -means method is a classical partition clustering algorithm [11, 16]. Clustering text divides the text into different clusters [1, 31, 75]. There is a high similarity between the texts in the same cluster but less similarity between different clusters [58].

Clustering is useful for analyzing social media information. For example, Neri et al. [45] studied sentiment analysis through text mining on Facebook and found that social media activity is useful for discerning customer loyalty and interests. Huang et al. [25] created an unsupervised event clustering algorithm to classify posts into different categories and concluded that the framework performs well in classifying events on social media. Salloum et al. [57] focused on how to find topics in data through text mining and conducted text mining research on Facebook and X. All these works demonstrate that text mining on social media is feasible and effective.

2.3 Sentiment Analysis of Social Media Information

Sentiment analysis of text refers to analyzing the sentiments reflected in the subjective text [3, 5, 8, 26, 64, 81]. Sentiment analysis is a common method in text mining, including customer review analysis and public emotional response [30, 42, 74] and can often reflect more valuable information [6, 48, 76]. The analysis of sentiment value comprised positive, neutral, and negative [80].

The three main ways to label sentiment value are supervised, unsupervised, and self-supervised. Supervised sentiment analysis is based on the labeled sentences in the dictionary to predict the words in the unlabeled text and add them to obtain the sentiment value of the sentence [19]. For example, Ray and Chakrabarti [54] conducted sentiment analysis on data collected from X using the supervised approach, developed an algorithm to estimate public sentiments, and completed the document and aspect levels analysis. For the unsupervised approach, Hu et al. [23] conducted an unsupervised sentiment analysis on X posts by using emotional signals to reveal the influence of emotional signals. The self-supervised sentiment analysis tool is also available for predicting the sentiment of a text. For example, Sousa et al. [62] conducted sentiment analysis on news articles through the **Bidirectional Encoder Representations from Transformers (BERT)** self-supervised sentiment tool to provide information for stock market decision-making. Based on the feasibility of these studies on social network analysis, this research conducted semantic social network analysis for user evaluation of innovative CACPs [72].

2.4 Semantic Social Network Analysis of Social Media Information

A social network structure is formed by the ties or connections between users when they share information [21, 27]. Semantic social network analysis is based on semantic analysis to study social networks. Many previous studies have used semantic social network analysis to analyze social media information. Ostrowski [47] analyzed semantic social networks by extracting relevant data from the X Web site and successfully correlated the results with market share. Pankong et al. [49] proposed a semantic social network analysis framework to recommend Web site user membership groups and extract explicit and implicit relationships from user activities. Danowski [14] used list-based semantic network analysis to collect texts from Facebook and discovered that the public network has become more complex with its growth over time.

Table 2. The Flagship Programs of Digital Supporters, Web Crawling Keywords for Data Collection, and Classification

Keywords	Issuing Date	Classification
Dunhuang Digital Supporters	December 29, 2017	Main Cooperation Program
Dunhuang Non-Fungible Token (NFT) Collector's Edition	September 6, 2021	NFT Program
Digital Library Cave	May 18, 2021	Cooperation Program
Dunhuang E-Tour	February 20, 2020	Interactive Experience Program (Platform: WeChat & QQ Mini-program)
Dunhuang Solar Terms		
Dunhuang Acoustic Animation		
Light up the Mogao Caves		
Dunhuang Animated Series		
Dunhuang Silk Scarves		
Ancient Music Rebirth	September 25, 2018	Concert
Honor of Kings (HOK) ^a		Video Game
Diao Chan—Meet Sogdian whirl version ^b	September 29, 2021	
Yao—Meet the Fairy Deer version	April 27, 2020	
Yang Yuhuan—Meet flying apsaras version	October 23, 2018	

^aHonor of Kings (HOK) was used as the main category of the game's classification, and only part of the game design is related to the "Digital Supporters" program. Therefore, HOK is not included in the keyword. ^bThe version refers to the appearance of a character in a game. In HOK, characters are usually designed with more than one skin to enhance the player's experience.

3 METHODOLOGY

This research aimed to measure the user evaluation of Dunhuang heritage culture by analysis combining Web and text mining strategies to provide some suggestions for promoting Dunhuang heritage culture in digital CACPs in the future, focusing on users' demands for Dunhuang heritage culture in CACPs on social media and the feasible trend of digital development of cultural heritage. The following subsections outline the details.

3.1 Data Extraction

We extracted the text by searching the posts that meet the user evaluations from the Weibo social platform⁴ in Dunhuang digital CACPs, which can include the most relevant users. As the collaboration between Dunhuang Academy and Tencent began on December 29, 2017, data collection commenced on that day and continued until July 10, 2022 (i.e., around 4.5 years). Table 2 shows the cooperation program keywords for Web crawling, issuing date, and program classification.

Based on Table 2, all the "Interactive Experience Programs" mentioned below represent the Dunhuang E-Tour interactive experience program. All the "Concerts" represent the Ancient Music Rebirth concert. All the "Games" or the "Video Games" represent the **Honor of Kings (HOK)** video game. Participants are the primary users who communicate and share information about the Dunhuang CACPs on the Weibo platform. This research uses Python (a popular general-purpose, high-level programming language) as the data crawling tool for social media data gathering. Particularly, this research scrapes the Web site with asynchronous loading using Tao's Python codes⁵ and then collects and parses the Web pages to get published Weibo posts [71].

⁴Weibo social platform is the main user review area for Dunhuang digital CACPs in China, and most domestic users like to share user experiences and user evaluations of Dunhuang products on this platform.

⁵Weibo Super Spider. URL: <https://github.com/Python3Spiders/WeiboSuperSpider>.

Table 3. The Flagship Program Explanation

Programs Translation	Explanation
Dunhuang Digital Supporters	Dunhuang Academy and Tencent jointly initiated the program.
Dunhuang NFT Collector's Edition	This NFT is a public welfare jointly released by Dunhuang Academy and Tencent.
Digital Library Cave	Dunhuang Academy and Tencent jointly initiated the program for the digital protection and promotion of Dunhuang culture.
Dunhuang E-Tour	Dunhuang Academy and Tencent jointly initiated the interactive experience program. Dunhuang Silk Scarves began before the release of Dunhuang E-Tour and were later merged into Dunhuang E-Tour after it was released. Dunhuang Acoustic Animation and Dunhuang Solar Terms belong to purely interactive programs. Dunhuang Animated Series belongs to the user dubbing project, and the Dunhuang silk scarf belongs to the User-Generated Content (UGC) project.
Light up the Mogao Caves	Dunhuang Academy and Tencent jointly initiated the interactive experience program. Dunhuang Silk Scarves began before the release of Dunhuang E-Tour and were later merged into Dunhuang E-Tour after it was released. Dunhuang Acoustic Animation and Dunhuang Solar Terms belong to purely interactive programs. Dunhuang Animated Series belongs to the user dubbing project, and the Dunhuang silk scarf belongs to the User-Generated Content (UGC) project.
Dunhuang Animated Series	
Dunhuang Silk Scarves	
Dunhuang Acoustic Animation	
Dunhuang Solar Terms	
Ancient Music Rebirth	The Dunhuang Academy and Tencent held the concert at The Third Silk Road International Exposition.
Honor of Kings (HOK)	In this video game, the characters are called "Heroes." The hero has many versions, called "Version." These three are Dunhuang versions of heroes released by Tencent and Dunhuang Academy.
Yang Yuhuan—Meet Flying Apsaras version	
Yao—Meet the Fairy Deer version	
Diao Chan—Meet Sogdian Whirl version	

Digital supporters was included as the main keyword among the six programs. Dunhuang E-Tour, Ancient Music Rebirth, and HOK were three other popular programs in the Digital Supporters program included due to their early start and many user discussions. Dunhuang **Non-Fungible Token (NFT)** Collector's Edition and Digital Library Cave were launched in the vicinity of 2022 and received less attention on Weibo then. Despite the Digital Library Cave launch in 2021, it only started to make new progress on July 13, 2022. Dunhuang NFT Collector's Edition program is a public welfare NFT program. However, since they are all part of the Digital Supporters program and a certain amount of discussion has taken place, these two programs are included in the keywords related to Dunhuang E-Tour, Ancient Music Rebirth, and HOK.

Table 3 briefly introduces these programs. As the entertainment form of concerts and games is more common and Dunhuang E-Tour is only on WeChat and QQ mobile applications, more descriptions of Dunhuang E-Tour interactive experience programs are detailed below. The CACPs of Dunhuang E-Tour comprises five modules. For Dunhuang Silk Scarves, users can create UGC designs through this module. Then, users can choose to take a screenshot to save their design products or purchase the UGC silk scarf. After purchasing the silk scarf, the merchant will send the silk scarf to the user. Dunhuang Animated Series is a pure user interaction module. Users can engage with the characters of the Dunhuang Animation Drama through user dubbing and learn about Dunhuang cultural stories through such interactions. Light Up Mogao Caves is an interactive landscape application that allows users to enjoy the night view of Mogao Caves at different times. It recreates the night view of the Mogao Grottoes as they were lit lamps a thousand years ago. Dunhuang Acoustic Animation is a quiz on Dunhuang E-Tour to raise funds for the Dunhuang cultural heritage. A certain amount of money is automatically donated to the Dunhuang Cultural Heritage Protection Fund when a user answers a question

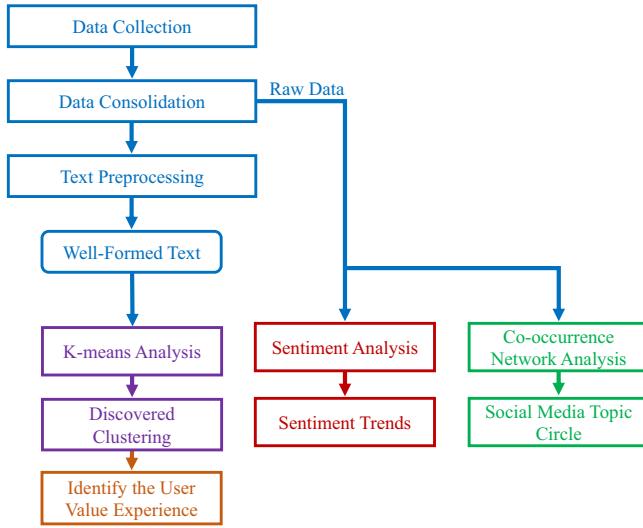


Fig. 1. Methodology framework.

correctly. For Dunhuang Solar Terms, users can select their birth date to receive a blessing card corresponding to their birthday on this module.

3.2 Data Pre-Processing

This research obtained public opinion data about social media networks from the Internet through Python software. Scraping Web sites through Python is the process of downloading Web site content from the Internet to the local computer to form a copy of the Internet content [33]. We obtained all the data needed after several scraping operations, deleted rows of data that were duplicate scraped, and then pre-processed the data. Next, we conducted data consolidation, cleaning, transformation, and reduction from the Web site data. After performing the four operations shown in Figure 1, well-formed data were obtained.

Text Noise Removal. There is usually some noise data in the data scraped from the Web sites, which is useless for the text analysis of this research and even affects the accuracy of data analysis [28]. The text was pre-processed to the data content through Python, including removing punctuation, special characters, HTML formatting, and deleting field-specific keywords, source code, and titles.

Stop Word Removal. Because the main target group of this research is Mainland users in China, English particles are seldom involved. This research collected the frequently used Chinese stop word databases (Chinese stop word collection, Harbin Institute of Technology stop word collection, and Baidu stop word collection) and the commonly used stop words on the Weibo platform to pre-process the data.

Chinese Text Segmentation. The core of text pre-processing is word separation. Text segmentation lexicon is needed in Chinese for vocabulary extraction [63], which differs from English. In this research, we used the “Jieba” system, an excellent third-party Chinese lexicon, to determine the probability of association between Chinese characters and then form word groups based on the probability of a more significant number of characters for the analysis [12, 38, 73].

k-Means Clustering. k -means is a classical clustering algorithm. This research conducted the k -means analysis by vectorizing the text. Elbow points were taken into account to determine the number of clusters. After determining the number of clusters, we used the “sklearn” package in Python to conduct k -means analyses to show the cluster

performance index evaluation (homogeneity, document, V-measure, **adjusted Rand-index (ARI)**, and Silhouette coefficient) and each cluster's top 10 high-frequency words.

Sentiment Analysis. We performed sentiment analysis utilizing the existing sentiment lexicon by classifying the words, scoring the sentiment value of the words, and finally obtaining the text's sentiment tendency [51]. Sentiment processing was based on the existing vocabulary in the in-network text sentiment analysis program. We used the Snow **natural language processing (NLP)** sentiment analysis tool based on the Bayesian model, widely used for supervised Chinese sentiment analysis [37], to analyze the text's sentiment intensity and orientation. Snow NLP can estimate each paragraph's sentiment with a score ranging [0, 1]. A value closer to 1 indicates a more positive sentiment in the paragraph, and a value closer to 0 indicates a more negative sentiment [11].

Semantic Social Network Analysis. After sentiment analysis, we conducted semantic social network analysis on the text extracted from the Weibo platform. A common method we employed is to extract social networks from names that appear in documents [72]. When users want to remind someone on Weibo, they can add text in the form of “@username” (e.g., @Dunhuang Academy) to the text. If a user forward another user's Weibo, the forwarded Weibo will automatically generate text in the “//@username:” format. Therefore, we analyzed social networks by extracting user names as reminders and retweeting from the original data.

4 RESULTS AND ANALYSIS

4.1 Overview of Data Collected

We collected valid data for 4.5 years, from December 29, 2017, to July 10, 2022, and a total of 202,896 posts were collected with regulations. The Dunhuang NFT Collector's Edition had 90 posts, the Digital Supporters program had 8,908 posts, the Ancient Music Rebirth concert had 2,807 posts, the Digital Library Cave program had 843 posts, the HOK video game had 156,451 posts, and the Dunhuang E-Tour interactive experience programs has 34,789 posts. As all personal data collected by users were screened and encrypted by the platform, our data collection process conforms to the ethical practice of the research. The Weibo platform has a diversified user base, including users of all ages and social sectors. Therefore, data collection has validity, reliability, and objectivity. Figure 2 shows the word cloud of the top 500 terms, and Table 4 records the top 50 frequent words in the dataset. Figure 2 and Table 4 indicate that the discussion about the Digital Supporters program on Weibo mainly focuses on the game, the concert, interactive experience programs, Dunhuang Academy, culture, and cultural heritage.

After data cleaning of the text, a term frequency ranking was carried out. About 70% of terms were about the HOK video game, as users of the video game have a high level of engagement on Weibo and comment over a long period. Regarding video game playing, game skills mentioned in Table 4 describe the character's ability to fight in the game by utilizing the effects of attack, defense, assistance, and so forth. Special effects in video games refer to many visual effects, such as the movement of characters and objects, explosive effects, and so forth. This article will further expand the discussion based on data analysis.

4.2 Elbow Method and k -Means Clustering Performance Metrics (for RQ1)

We used the elbow method to select the optimal number of clusters by fitting the model with a range of K values. The value of Y decreases as the number of clusters increases (value of X). When there is an elbow formation in the figure, that point is the optimal number of clusters. Figure 3 shows the elbow method result based on the total terms of the six programs. Figure 3 shows where $K = 11$ is the elbow point of this cluster. Therefore, the optimal K of clusters is 11.

Table 5 shows the performance evaluation metrics of clustering based on six programs. The V-measure value is the harmonic mean of the homogeneity value and the completeness value in [0, 1]. The higher the value of the V-measure, the better. The ARI and silhouette coefficient values range in [-1]. A higher value for these two indicators indicates a more accurate clustering result. In this research, as a result of a large amount of data, the V-measure, ARI, and silhouette coefficient values were all within the acceptable range.

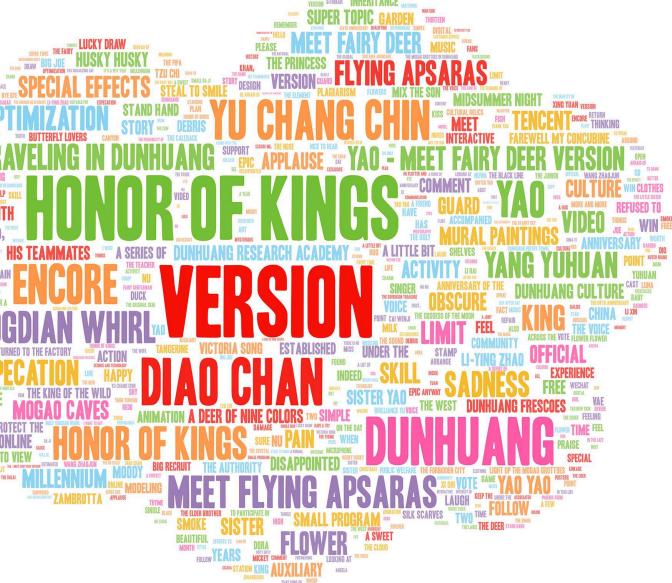


Fig. 2. Word cloud of top 500 terms in the dataset.

After determining the optimal K value by elbow point, we clustered the text with 11 clusters. Table 6 shows the top 10 terms with the highest frequency in each cluster based on all these six programs. Clusters 2, 3, 4, 6, 9, 10, and 11 are about the HOK video game. Versions, special effects, posters, and Dunhuang accounted for 42.9% of the terms in these clusters. These categories related to Dunhuang are the most concern for users when playing games. In addition, Clusters 4 and 10 focus on the terms of game festival promotion in the game, such as “Yang Yuhuan,” “Meet fairy deer version,” “5V5 Socializing Day,” and “Back-to-school activity.” Notably, Dunhuang versions of Yang Yuhuan and Yao characters are prevalent at festivals and activities.

Clusters 7 and 8 connect the HOK game to the interactive experience programs and Digital Supporters program. The two clusters indicate that users will also learn about the Dunhuang Digital Supporters program and interactive experience programs by using the Dunhuang version of the characters in the game.

Cluster 1 is about the interactive experience programs cluster. The terms with high frequency in Cluster 1 focused on Dunhuang E-Tour, Dunhuang Silk Scarves module, Dunhuang Animated Series module, dubbing, mural paintings, Light up the Mogao Grottoes module, and so forth. These terms mainly refer to the user interact products, UGC products, interactive landscape applications, and Dunhuang elements in the Dunhuang E-Tour.

Cluster 5 is about singers and songs. The terms in this cluster are mainly singers, bands, and song names at the Ancient Music Rebirth concert. This cluster shows the attention and engagement of users to the concert. The star singers are mentioned many times in the clustering, and it also shows users can learn about Dunhuang culture by following their favorite singers.

4.3 Analysis of the User Value Experience Framework (for RQ2)

The user value experience framework mentioned above [67] has three stages: pre-, during-, and post-experience. Most (70.0%) terms in these clusters in Table 6 (Clusters 2, 3, 4, 6, 9, 10, and 11) refer to Phases 1 and 2 of the Value Experience (“Support,” “Shruggie,” “Meet Sogdian whirl,” “Meet flying apsaras,” “Special effect,” and “Masterstroke”). These posts demonstrate that few users have reached the outcome phase of the game (i.e., Phase 3). The user experience process should be throughout every phase [65]. The results show that video games are not the

Table 4. Top 50 High-Frequency Terms

No.	Term	Frequency	No.	Term	Frequency	No.	Term	Frequency
1	Version	22,848	18	Yao—Meet the Fairy Deer version	3,688	35	Culture	2,007
2	Honor of Kings	18,513	19	Flower	3,551	36	Activity	2,005
3	Dunhuang	10,269	20	Limit	3,316	37	Sister	1,919
4	Diao Chan	9,861	21	Game	3,239	38	Guard	1,875
5	Encore	7,081	22	Special effects	2,996	39	Applause	1,874
6	Yu Chang Chin	7,039	23	Video	2,989	40	Dunhuang Research Academy	1,869
7	Yao	5,928	24	Meet fairy deer	2,939	41	Version (Abbreviation of “Version” in Chinese)	1,825
8	Honor (A general term for a game character)	5,002	25	Skill	2,803	42	Query	1,803
9	Meet Flying Apsaras	4,695	26	Xi Shi	2,636	43	Dunhuang culture	1,801
10	Meet Sogdian Whirl	4,546	27	Tencent	2,356	44	Super topic	1,798
11	Dunhuang E-Tour	4,409	28	Mogao Caves	2,306	45	5V5 Socializing Day	1,791
12	Yang Yuhuan	4,336	29	Millennium	2,284	46	Sister Yao	1,761
13	Sadness	4,270	30	Yao Yao	2,115	47	Husky husky (Silly in Chinese)	1,740
14	King (Abbreviation of the “HOK”)	4,171	31	Mural Paintings	2,097	48	Story	1,675
15	Expectation	4,169	32	Obscure	2,094	49	Follow	1,652
16	Flying apsaras	3,991	33	Pain	2,094	50	Comment	1,644
17	Optimization	3,882	34	Official	2,090			

CACPs type that gives users a profound experience of Dunhuang culture. Therefore, this part further investigated the phases of value experience from interactive experience programs and the concert considering this situation. Since video games account for about 70% of the total term count in the previous clustering, separate clusters were conducted for interactive experience programs and concerts.

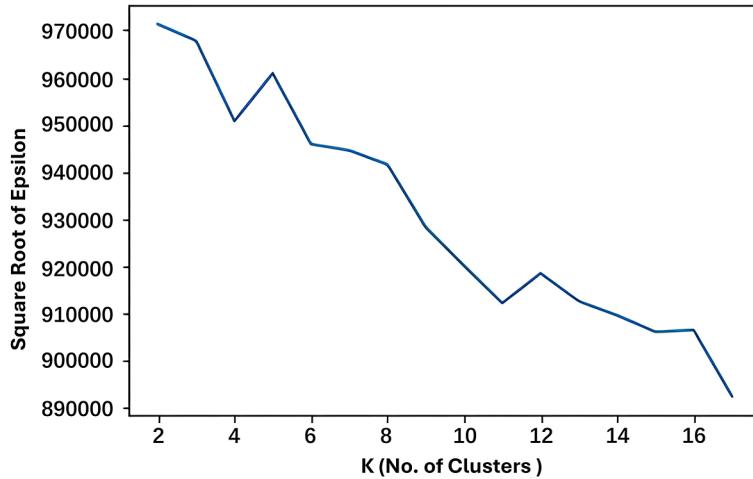
Fig. 3. The elbow method showing the optimal K .

Table 5. Clustering Performance Evaluation Metrics

Clustering Performance Metrics	Value
Homogeneity	0.520
Completeness	0.184
V-Measure	0.272
ARI	0.137
Silhouette coefficient	0.118

Figures 4 and 5 show the optimal cluster number of elbow points for the two clusters. The best cluster number for concerts is 4, while the best for interactive experience programs is 7. The two categories of Weibo posts were next clustered based on these two elbow points.

In Table 7, most users discuss their feelings about singers and songs when recalling and discussing them. Therefore, most users' value experience phase is in the third phase of enjoyment and entertainment experience. In Table 8, the terms include the users' discussion of the product, their expectations, the process of use, and the feeling of enjoyment after use. The interactive experience programs evenly cover Phases 1, 2, and 3. It provides users with a well-rounded cultural experience.

4.4 Sentiment Analysis Results (for RQ3)

We also analyzed the sentiment outcomes of interactive experience programs, the concert, and the video game because these are three top-rated programs related to valuable user experiences. Each category has a sentiment statistic based on its period. Figures 6–8 show the weekly sentiment average values for the three programs.

Table 9 shows the quartiles of average sentiment values for each category. In Table 9, the concert's minimum, Q1, median, and Q3 sentiment values are the highest of the three categories (min = 0.3340, Q1 = 0.8009, median = 0.9742, and Q3 = 0.9999). For interactive experience programs in Figure 7 and Table 9, the longer period and the high weekly median sentiment values indicate that users generally have a good evaluation of the program (median = 0.7990). For video games in Table 9, the values of Q1, median, and Q3 are the lowest of the three categories (Q1 = 0.5914, median = 0.6287, and Q3 = 0.6805).

Table 6. Top 10 Terms of Each Clustering

Cluster ID	Description	Top 10 Terms per Cluster
1	Dubbing, silk scarves, and landscape applications in the interactive experience programs	Dunhuang E-Tour, Dunhuang, Mini-programs, Silk scarves, Mogao Caves, Meng Jia (Singer), Dunhuang Animated Series, Dubbing, Mural Paintings, and Light up the Mogao Caves Optimization, The Cloud, Tangerine (Version in the HOK), Dream Maker (Version in the HOK), The Life, Love, Player, Summer (Version in the HOK), Zhen Ji (HOK character), and Vote
2	Other game character versions not related to Dunhuang	
3	Different versions and special effects of the character Diao Chan	Diao Chan (HOK game character), Meet Sogdian Whirl (Version in the HOK), Version, Launched, Dunhuang, Elder sister, Video, Weibo, Special effects (Game term), and Midsummer Night (Version in the HOK)
4	Promotion of large festivals in the game and user focus on the versions of the characters	Version, Meet flying apsaras (Version in the HOK), Encore, Yang Yuhuan (HOK character), Meet fairy deer, Honor, Limited edition, 5V5 Socializing Day (HOK game festival), King, and Dunhuang
5	Singers and their songs in the concert	Digital Supporters, Yu Chang Chin (Singer), Nice music, Xu Song (Singer), Graphics Interchange Format (GIF), Dunhuang, Western Regions, Music, Song Xi (Singer), and Good sister (A band name)
6	Game skills	Wild King (Game term), Honor, Player, Skill (Game term), Loiterer, Support, Teammate, Play Yao (Use the Yao Version), Shruggie, and Game
7	Interactive experience programs terms and terms of users' affection for the game characters	Yao—Meet fairy deer, Weibo, Cute, Video, Dunhuang, Game, King, Dunhuang E-Tour, Millennium (Interactive Experience Programs term), and Tencent
8	Digital Supporters program terms and game events	Love you, Flying apsaras, Encore, Dunhuang E-Tour, Digital Supporters, Yang Yuhuan, Encore (An alternative way to write “encore” in Chinese), Liang Zhu (Version in the HOK), Yang Yuhuan, and Version
9	Character versions voting activities and terms of the special effects and skills of the character versions	Skill, Xi Shi (HOK character), Husky (silly), Special effect, Refuse, Wild king (Game term), Masterstroke (Game term), Hand feel (User's feelings when playing the games), Vote, and Honor
10	Special effects and skills of the character versions in the game	Encore, Dunhuang E-Tour, Sister, Sadness, Yu Chang Chin, Limited edition, Meet Fairy Deer, Back-to-school activity (HOK activity), Yang Yuhua, and Yao Yao (HOK character)
11	Character posters and character effects in the game	Special effects, Player, True, Hand feel, Poster, Wild king, Shruggie, Plagiarize, Original picture, and Yang Yuhuan

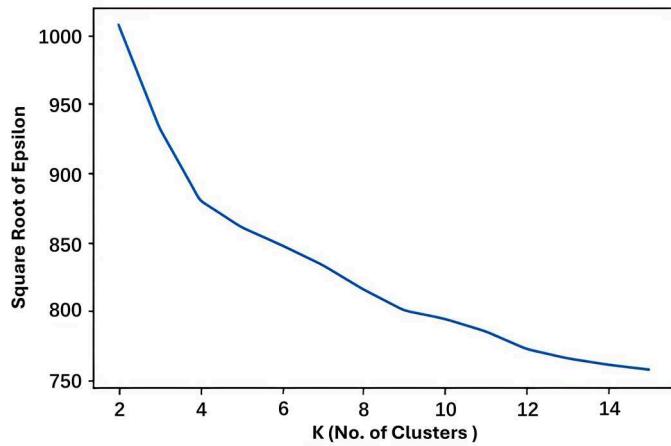


Fig. 4. The elbow method for concerts.

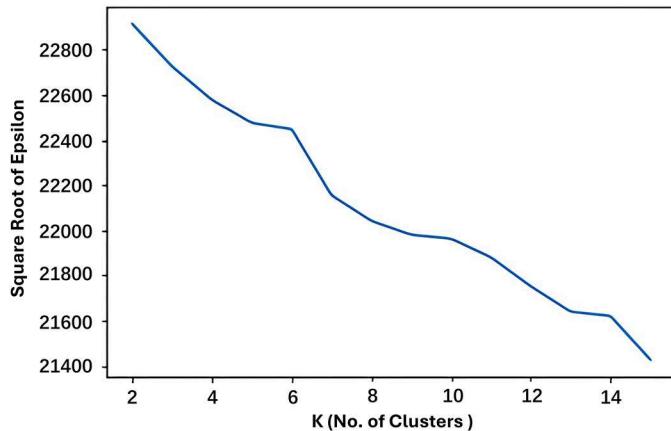


Fig. 5. The elbow method for interactive experience programs clustering.

Table 7. Clustering of the Concert

Cluster ID	Terms	Value Experience Phases
1	Love You, Patent Rights, Hit the Like Button, and Like	3
2	Weibo, Follow Each Other, Comment Each Other, Fresh Flower, Music, Sun, and Target	2 and 3
3	Anniversary, Happy, Debut, Youth, Strength, and Flew	3
4	Xu Song (Singer), Galloping (Song), Song the First Time, New, Treasure, Single Song, Rebirth, Ancient Music, Dunhuang, and Assistance	1, 2, and 3

Table 8. Clustering of the Interactive Experience Programs

Cluster ID	Terms	Value Experience Phases
1	Mogao Caves, Light up the Mogao Caves, Celebrate the Spring Festival, So Beautiful, Chance, Protection, and Dunhuang	2 and 3
2	Mini-program, Silk Scarves, Dunhuang Academy, WeChat, Dunhuang Silk Scarves, Online, and Culture	1 and 2
3	Heart, Dubbing, Expectation, Lovely, and Voice	1 and 2
4	Arrange, Interaction, Fashionable Dress, Journey, and Appearance	1 and 2
5	Following, Mini-program, Miss, Time, Thank You, Cultural Heritage, Sharing, and Flying Apsaras	3
6 ^a	HOK, Encore, Flying Apsaras, Version, Player, and Skill	
7	Good, Mini-program, Dunhuang, Dubbing, Creativity, Silk Scarves, and Affirm	2 and 3

^aPosts often contain more than one comment on a single program. Since the terms in Cluster 6 belong to the category of the HOK video game, they are not analyzed.

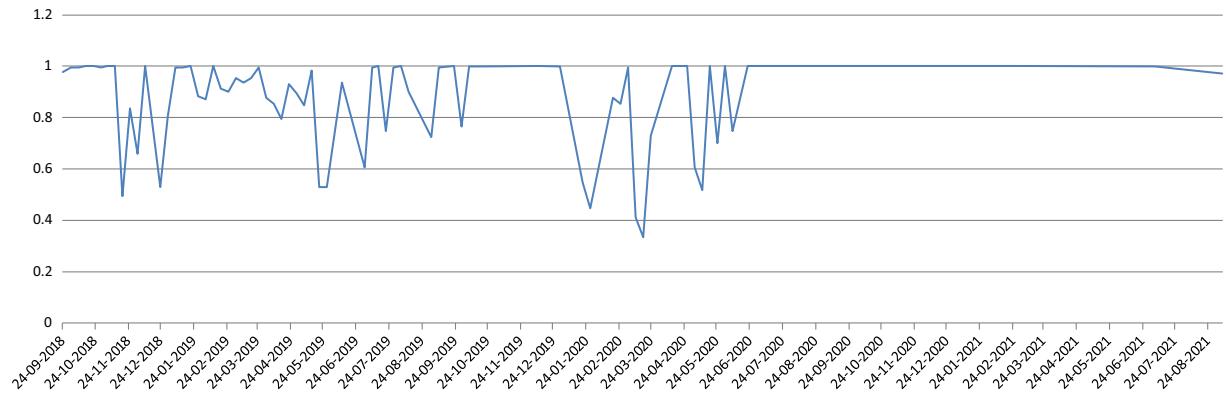


Fig. 6. Weekly sentiment: Ancient music rebirth concert.

Combined with the k -means analysis, the aggregation category of concert terms mainly comprises the Weibo platform, like singers and songs. Thus, even though concert programs are short, star singers and music can draw users' attention and generate positive comments. The cluster of Dunhuang terms of the interactive experience programs is mainly related to dubbing, the interactive landscape application, and so forth, reflecting users have a good evaluation of the innovation in the interactive experience programs. As some terms in the video games' term clustering are mainly related to game characters, skills, and battles, the games' winning, losing, and character skills may affect the distribution of sentiment values. Therefore, the median sentiment value of the video game (median = 0.6287) is significantly lower than the values of the concert (median = 0.9742) and the interactive experience programs (median = 0.7990) in Table 9. Although interactive experience programs have a slightly lower median sentiment value than concerts, their duration is long enough to keep updating and keep users' positive attention.

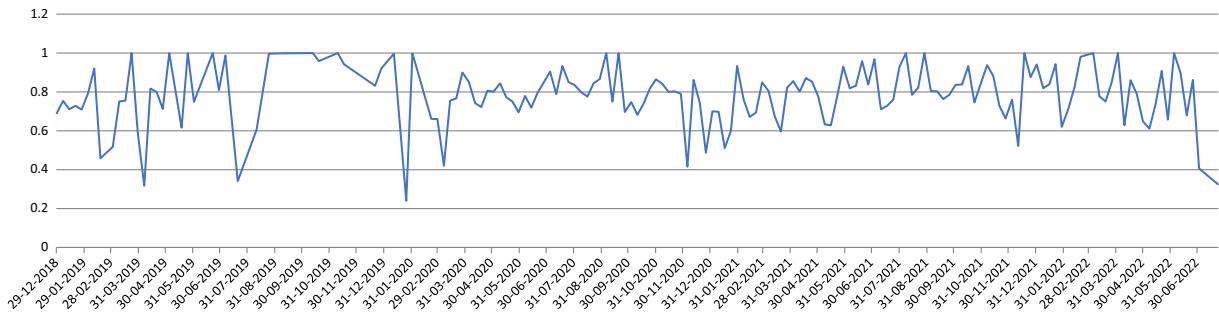


Fig. 7. Weekly sentiment: Dunhuang E-Tour interactive experience.

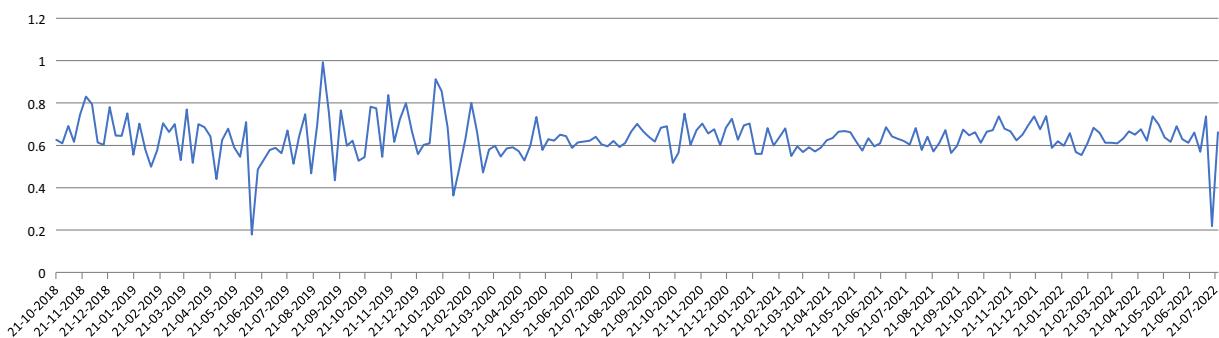


Fig. 8. Weekly sentiment: HOK video game.

Table 9. Quartiles of Weekly Average Semantic Value of Each Program Classification

Programs	Min	Q1	Median	Q3	Max
Concerts	0.3340	0.8009	0.9742	0.9999	1.0000
Interactive experience programs	0.2399	0.7105	0.7990	0.8724	1.0000
Video games	0.1783	0.5914	0.6287	0.6805	0.9925

4.5 Semantic Social Network Analysis Results (for RQ4)

Figure 9 shows the visualization of the semantic social network analysis of all the texts of six programs in this study. The larger the node in the figure, the more it interacts; the thicker the line, the closer the connection between them. The figure can be subdivided into eight broad categories, and Figure 10 details each category. The numbers in Figure 10 correspond to the numbers in Figure 9.

Figure 10(1) shows the official media circle of Dunhuang culture. As the Dunhuang cultural heritage is located in Gansu Province, we can generally find “Gansu Publish” and “Lanzhou⁶ Morning Post.” Some users of Dunhuang CACPs and Dunhuang Tourism mentioned or forwarded related posts to each other.

Figure 10(2) shows the museum circle. The reason for the relationship between movie dubbing companies and museums is that relevant movie dubbing companies participated in producing dubbing parts in the Dunhuang Animated Series module, so there is a specific relationship between them. Another cooperation between The

⁶Lanzhou is the capital city of Gansu Province.

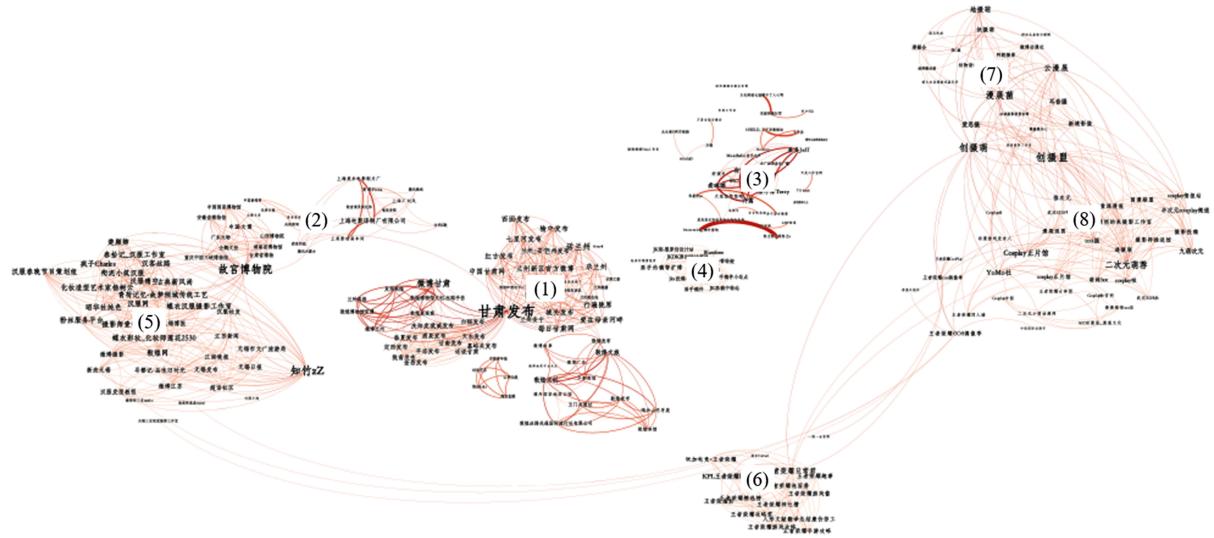


Fig. 9. Visualization of semantic social network analysis (overall).

Palace Museum⁷ and Dunhuang Academy also happened in 2021. Users may mention or retweet the Palace Museum and Dunhuang Academy posts in their Weibo comments. Therefore, the “The Palace Museum” node in this circle is large. Other museums will forward or mention related posts, so there is a circle of museums.

Figure 10(3) shows the circle of singers and stars. Most of the stars and singers in the circle participated in the concert. There are also stars like “Ouyang Nana Studio”⁸ in Figure 10(3). Although they did not participate in the Ancient Music Repertoire concert, they were involved in other programs related to the Digital Supporters program. Even if some stars were not involved in this program, they were also associated because they participated in activities related to disseminating Dunhuang cultures, such as the star user “Zhang Yixing”⁹ in Figure 10(3).

Figure 10(4) shows the original drawing design circle, commonly referred to as key animation design. As with the term “Original Picture” mentioned in Clustering 11 of Table 6, this group of users is interested in forwarding some original design pictures, including the original design of the Dunhuang version of the HOK video game. However, this circle is relatively small and may not be sustainable.

Figure 10(5) is about the Hanfu¹⁰ cultural circle. In this circle, most of the dissemination related to Dunhuang cultural clothing is related to the Digital Supporters program. As the Hanfu culture has been developing in China for many years, and Dunhuang culture is crucial in the Hanfu culture, Dunhuang culture and related cultural programs also spread in this circle. Notably, the Hanfu culture circle is closely connected to the museum circle. Therefore, the museum posts also had a certain influence on the Hanfu culture circle.

Figure 10(6) mainly shows the King Pro League (KPL)¹¹ circle of the HOK video game. The KPL circle is formed when many of these characters or versions related to the Digital Supporters program are involved in the game discussion during KPL.

⁷The Palace Museum and the Dunhuang Academy jointly launched the exhibition “Beyond the Bounds of History” on September 17, 2021.
⁸“Ouyang Nana Studio” is Ouyang Nana’s studio Weibo. Ouyang Nana is a star and the official ambassador for the Dunhuang Silk Scarves module.

⁹“Zhang Yixing” is Zhang Yixing’s Weibo username. Zhang Yixing is a star who has sung a song about Dunhuang culture called Flying Apsaras.

¹⁰Hanfu is a traditional type of Chinese clothing.

¹¹The KPL is a professional league of HOK games organized by Tencent.

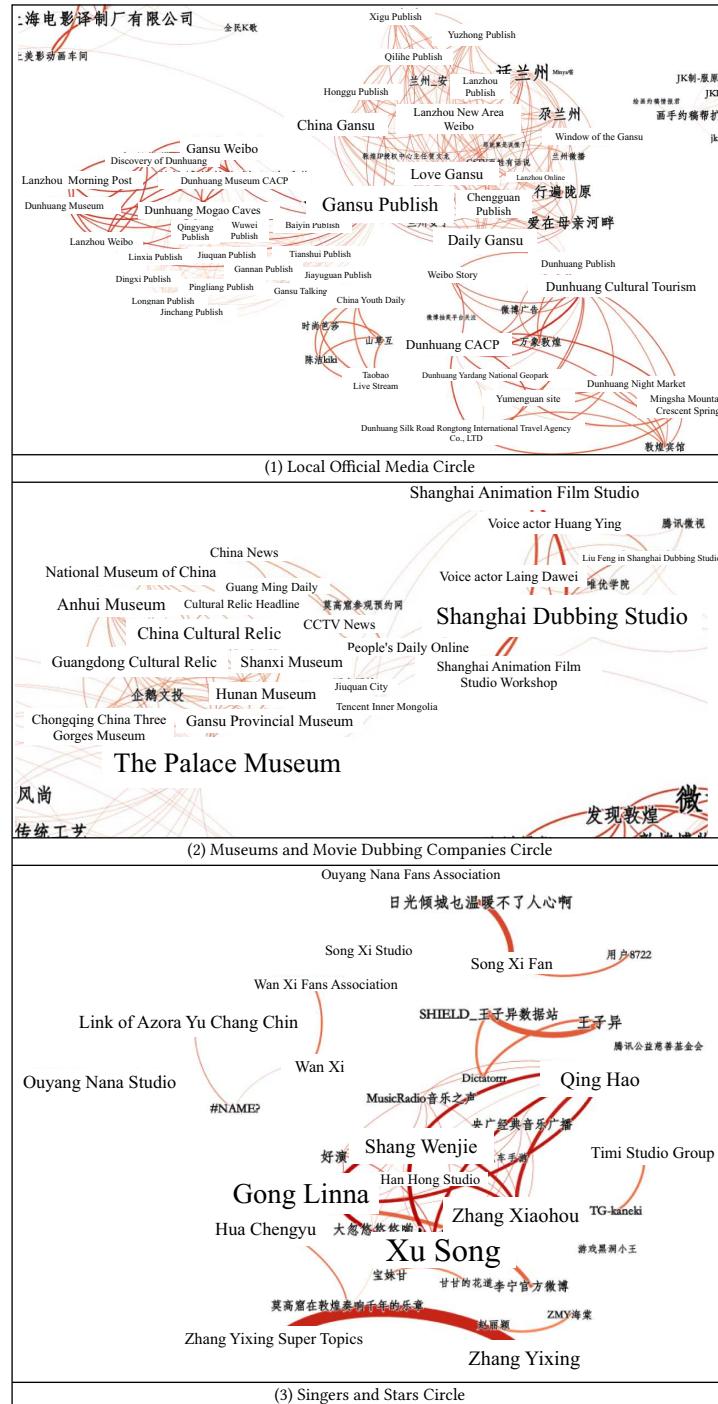


Fig. 10. Detailed visualization.

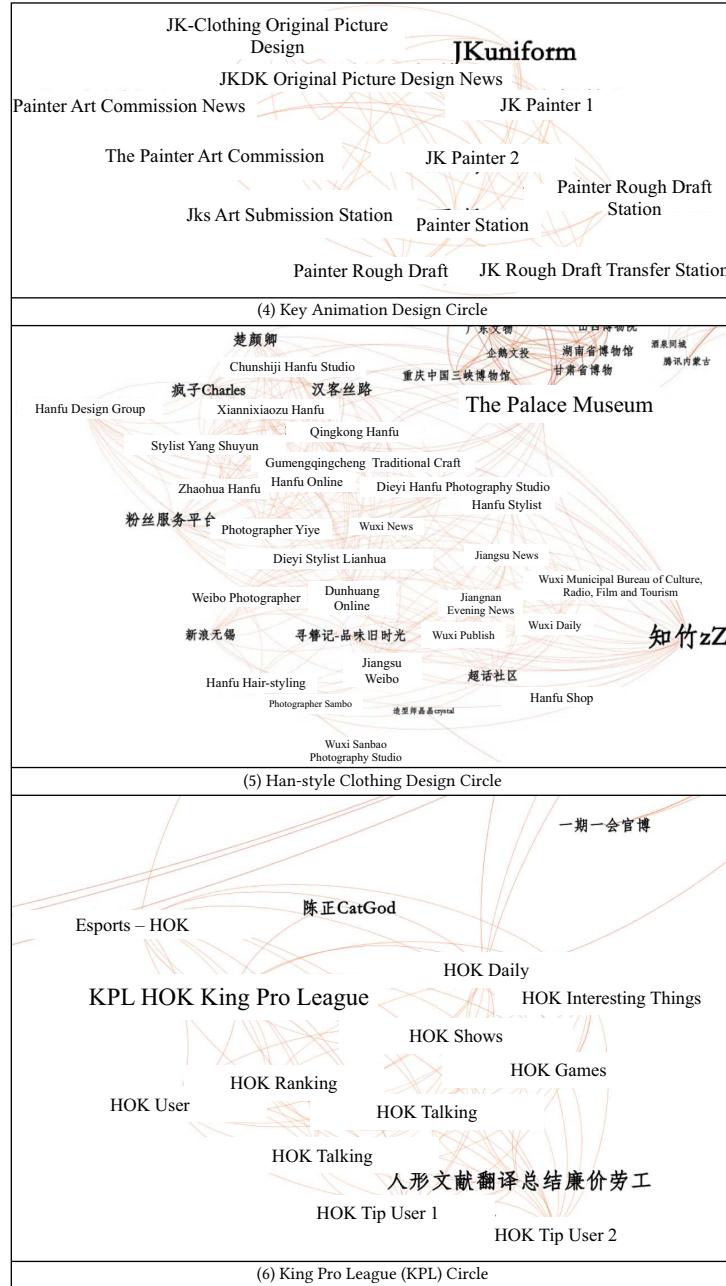


Fig. 10. Continued.

Figure 10(7) and (8) are **Animation Comic Game Novel (ACGN)** Exhibition¹² and cosplay¹³ circles. Notably, these two circles have a relationship in Figure 9 because it is common for cosplayers to appear at ACGN exhibitions.

¹²ACGN Exhibition is an event with a primary focus on animation, anime, manga, games, and comic book themes.

¹³Cosplay, also known as “costume play,” refers to the use of costumes and accessories to act as specific characters in animation, anime, manga, games, and so forth.

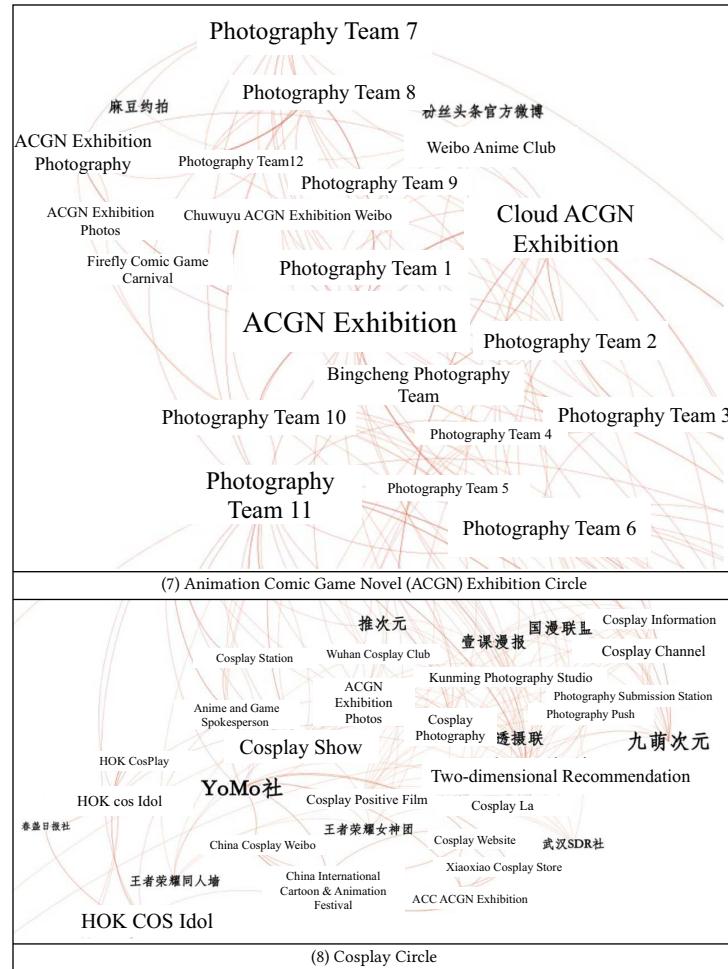


Fig. 10. Continued.

It can be seen from Figure 10(8) with users such as “HOK CosPlay,” “HOK COS Idol,”¹⁴ and so on, indicating that the influence of the HOK video game also involves the cosplay circle. Pictures of cosplay of the HOK game characters are often reposted on these Weibo posts. Thus, cosplay of the Dunhuang element is also prevalent in this circle, indicating high consumer interest in these costumes.

5 DISCUSSION

This research provides a novel perspective to summarize the communication effects and influences of digital CACPs and directions for future research, as discussed in the following subsections.

5.1 Sentiment Analysis Results (for RQ1)

Through k -means clustering, Dunhuang characters' posters, skills, and special effects seem highly interesting to video game users. Users tend to pay more attention to versions of game characters during game festivals

¹⁴The “HOK CosPlay” and “HOK COS Idol” are both about the HOK video game cosplay users.

and voting activities, reflecting the successful innovation of cultural element applications. As for interactive experience programs, the clustering indicates that the CACPs of Dunhuang Silk Scarves, Dunhuang Animated Series, and Light up the Mogao Grottoes have been widely discussed by users on Weibo, reflecting their higher interest in user interact products, UGC products, and landscape applications. Most users are also interested in the singers and their songs for concerts. The clustering mentioned the star singers many times, showing users can learn about Dunhuang culture by following their favorite singers.

5.2 Deep User Experience of Innovation CACP (RQ2)

Examining the resultant cluster content reflects that most users' value experiences were in the first and second phases of the video game, providing further hints of innovation application. This means most game users value experiences of this cultural heritage, and this digital CACP tends to focus more on the product's sensory, emotional, and informational aspects than on creating a sense of enjoyment, skill, or nostalgia. In other words, by using video game CACPs, users are engaged and can learn more about cultural heritage through basic cultural symbols and the appearance of virtual products rather than through enjoyment, recall, or in-depth understanding of the cultural heritage represented by these CACPs.

Most users' value experiences are of the concert in the third phase. Thus, users are more likely to remember and enjoy the song and the performer with this type of CACP, even if the project members have provided hundreds of relevant details about cultural heritage online. For example, more users may enjoy a song because of their favorite singers but may not actively search for content and culture related to that song. The innovative interactive experience programs evenly cover the entire value of the experience of this phase, meaning that this type of user's value experience includes searching for, understanding, imagining, anticipating, using, and making fond memories of the innovative CACP through intellectual exploration. Therefore, interactive experience programs can give users the most profound experience of Dunhuang culture, which is very similar to previous research findings [41]. Interactive experience programs innovatively combine the features of spatial games, puzzles, and trivia games mentioned in Malegiannaki and Daradoumis [41] research and bring users a comprehensive cultural experience.

5.3 Arousing Users' Continuance of Positive Views (RQ3)

Sentiment analysis reveals that continuous updates and star-effect programs have significantly improved users' continuous attention to and positive evaluation of the Dunhuang digital CACPs. Keeping game content relevant to the program updated can also keep users engaged for a longer time, which is consistent with previous research findings [82].

5.4 Weibo Circles for Better Promotion of Innovative Digital CACPs (RQ4)

The thickness of the lines between nodes in Figure 10(1), (2), and (3) of the semantic social network analysis indicates that the local official media circle, museum circle, and star circle are closely connected to promoting innovative Dunhuang CACPs. These are also the three main communication circles related to Dunhuang CACPs. On the other hand, the Hanfu, ACGN exhibition, and cosplay circles are gradually developing. Despite the thin edges between these three circles in Figure 10(5), (7), and (8), the large number of nodes in these circles should not be underestimated, indicating potential venues to promote Dunhuang CACPs. Marketers can also try to promote more CACPs in these circles.

5.5 Practice Implications

This research analyzes the user evaluation of experience programs in the CACPs industry. The experience programs covered include mobile interactive experience programs, concerts, and video games. The user evaluation of Digital Library Cave and the Dunhuang NFT Collector's Edition is not represented in the Weibo analysis,

Table 10. Comparison of Interactive Experience Programs, Concerts, and Video Games

Classification	Sustainability of Cultural Promotion	Positive Sentiment Response	Point of User Concerns	Comprehensiveness of Cultural Value Experience
Interactive experience programs	A long overall sustainable duration	The overall sentiment of user response is higher	The content of the program relates to the cultural heritage itself	It can provide a comprehensive cultural value experience (Phases 1, 2, and 3)
Concert	A long overall sustainable duration online	The overall sentiment of user response is the highest	Singers, stars, and songs that relate to the cultural heritage	Mainly in the outcomes phase (Phase 3)
Video game	A long overall sustainable duration	The overall sentiment of user response is neutral	The game itself or the character posters that relate to the cultural heritage	Mainly in the activities and value sources phase (Phases 1 and 2)

reflecting that these two programs have not been fully established or promoted in the Digital Supporters program before 2022. For interactive experience programs, concerts, and video games, this study makes the following comparisons in Table 10.

This research analyzes CACPs from various innovation angles for researchers and entrepreneurs in the digital CACPs industry. First, exploring different digital CACPs is conducive to spreading cultural heritage [53], and such innovation has successfully engaged users. As shown in Table 10, each type of digital CACP has different characteristics and can be used to combine products to provide users with a more comprehensive understanding of cultural heritage, thus further engaging users. For example, concerts can be combined with interactive experience products for joint promotion by taking advantage of its characteristics of positive sentiment feedback from users to achieve extensive and in-depth dissemination of the cultural heritage.

Further, as part of CACPs industry communication, we should encourage the collaborative development of digital CACPs and consider how online and offline products can be combined [60]. Landoni et al. [34] mentioned that in the maturity stage, creative and cultural and creative companies need to innovate their product portfolios to continue to develop. The Digital Supporters program has engaged many users by combining online **do it yourself (DIY)** production with offline delivery of DIY finished products. Therefore, CACPs products should be designed to allow users to participate in various ways, including a combination of digital CACPs and online and offline products, so that all users can have more opportunities to participate.

6 CONCLUSIONS

This research aims to improve the current understanding of the development status of innovative digital CACPs through social media analytics of user evaluation of three types of digital CACPs in the cultural heritage field. The CACPs industry is increasingly trying to develop innovative digital products in the Web 3.0 era [36, 61, 78]. Despite the great potential of such products, the mode of dissemination and the effects of the cultural heritage represented by such products still need better understanding and improvement. Through three different clustering methods, sentiment analysis, and semantic network analysis, this research examines users' favorite design elements, value experience, and sentiment about innovative digital CACPs on social media. Aligning with Rizvic et al. [56] of the content creation field, appropriate content can innovatively provide a distinctive visual identity. The Digital

Supporter program has innovatively used multimedia by creating short and informative cultural stories and received good feedback.

Our semantic social network analysis has explored the current user groups of the Digital Supporters program. Some active users continuously promote the CACPs and connect these user groups and potential users of the Digital Supporters program, enabling the further promotion of these CACPs. Our results show that the mainstream is the official media and star groups. Potential groups are the Hanfu circle and ACGN circle, and so forth. Hanfu, ACGN, and cosplay groups mainly hold offline activities, clearly showing the importance of the innovative co-development of digital and physical products.

As one of the vital pillar industries for the future development of innovative CACPs, spreading history and culture through digital CACPs to engage users is crucial [20, 46, 77]. This research reveals that video game elements, concert elements, and interactive experiences are generic components of products, and these attractions have successfully motivated users and engaged them to learn more about the cultural knowledge contained within these elements. These elements provide deeper insight into Dunhuang's artistic and historical worlds as channels for users to comprehend better and appreciate the cultural heritage. In light of the importance mentioned above of spreading history and culture through digital CACPs, the findings of this research provide some substantial contributions. First, this study collected data from social media, which integrated many reviews of multiple digital CACPs products, which can provide the basis for future research. Second, this research classifies and discusses the evaluation of different types of digital CACP products and expands the previous literature on digital CACPs, which is especially useful for promoting multiple digital CACPs. Finally, this research integrates the primary and potential user groups in this field in the context of social media. Potential users have shown interest in cultural heritage products that adequately support future innovation research and projects.

This study also has limitations that provide multiple future research directions. Despite analyzing valid data from 202,896 Weibo posts, this research did not cover other social media. Considering the limited number of comments in other languages than Chinese on Dunhuang CACPs, comparing comments in other languages with Chinese is challenging. Hence, this research focuses solely on Chinese user posts as a starting point. Since this research relied primarily on text mining methods, future research should use more specific classifications and detailed user surveys. As this research discovered that approximately 80% of Weibo users are young, and users of midlife and elderly groups are less likely to comment on Weibo, future research can explore game server databases and interview more users to gather targeted data. As this research focused solely on the "Digital Supporters" program and did not investigate other digital CACPs, more cases should be investigated. By exploring user evaluations of more digital CACP programs, entrepreneurs can compare and summarize the needs of more user groups, which helps them improve and innovate digital CACPs. In addition, as the Digital Library Cave and the Dunhuang NFT Collector's Edition have not been fully established before 2022, we plan to study them in the next phase.

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