

Danmaku: A New Paradigm of Social Interaction via Online Videos

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Danmaku is a new commentary design for online videos. Unlike traditional forums where comments are displayed asynchronously below a video screen in order of when the comments are posted, danmaku comments are overlaid on the screen and displayed along with the video. This new design creates a pseudo-synchronous effect by displaying asynchronous comments with certain video segments in a synchronous fashion, and the links between danmaku comments and the video segments are defined by users. Danmaku is gaining popularity; however, little is known, compared to the traditional forum design, regarding how effective the new danmaku design is in promoting social interactions among online users. In this work, we collected 38,399 danmaku comments and 16,414 forum comments posted in 2017 on 30 popular videos on Bilibili.com. We compared user participation from different perspectives, e.g., number of comments, sentiment of the comments, language patterns, and ways of knowledge sharing. Our results showed that compared to the traditional linear design, the danmaku design significantly promoted user participation, i.e., there were more users and more comments in danmaku. Additionally, active users posted more positive comments, though they were anonymous; more linguistic memes were used in danmaku, suggesting that it was used to facilitate community-building. In addition to its effectiveness in promoting social interactions, our results also show that danmaku and forum designs play complementary roles in knowledge sharing, where danmaku comments involved more explicit (know-what) knowledge sharing, and forum comments exhibited more tacit (know-how) knowledge sharing. Our findings contribute to the development of social presence theory and have design implications for better social interaction via online videos.

CCS Concepts: • Human-centered computing → Collaborative and social computing systems and tools;

Additional Key Words and Phrases: Danmaku, online videos, forum comments, social presence, anonymity, synchronous, knowledge sharing, explicit knowledge, tacit knowledge

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1 INTRODUCTION

Danmaku, a new commentary design for online videos, originated in Japan and now is very popular on Asian video websites (e.g., Bilibili.com, AcFun.cn, Niconico.jp, dilidili.wang), especially among young people in China [65]. Unlike traditional video forums where comments are displayed asynchronously below the video in order of when the comments are posted, danmaku comments are overlaid on the video screen. Depending on which video scene online users choose to associate their danmaku comments with, danmaku comments appear and fly from right to left on the video screen. Users can send danmaku comments anonymously and see other users' danmaku comments in a synchronous fashion while they are watching videos. Figure 1 illustrates the two commenting designs using an example on Bilibili.com [9].

Compared to the forum design that has been widely applied to the majority of video websites across different nations (e.g., YouTube) [52, 79], danmaku is currently adopted by video websites mainly in Asia. There has been an increasing interest in the CSCW and CHI communities over the new social phenomena created by danmaku, e.g., References [49, 78, 97]. However, these two designs have been studied separately. For example, scholars found that users posted forum comments for varying purposes, e.g., sharing ideas, networking, and answering questions [52], as well as debating [79]; users perceived that danmaku made the videos more fun, though there was a large number of critiques and insulting language [97], and they used different colors to distinguish user groups [49].

In this work, we collected 38,399 danmaku comments and 16,414 forum comments posted in 2017 on 30 recent and popular videos on Bilibili.com (the most popular danmaku video website in China). We compared these two designs in terms of user participation, collective emotions, language patterns, and ways of knowledge sharing by sending comments. This article is an extended version of work published in Reference [96]. We extend our previous work by further investigating collective emotions and linguistic patterns of danmaku and forum comments. Our work contributes the following major findings: (1) The new danmaku design is more effective in promoting user participation than traditional forums, with a larger number of users participating in sending more comments; (2) Even though there was more negative language in danmaku than in forum comments overall, active users appeared to post more positive danmaku comments, which contained more linguistic memes that stem from more diverse cultures; (3) Danmaku and forum comments play complementary roles in promoting sharing knowledge, i.e., more explicit knowledge (know-what) is shared in danmaku and more tacit knowledge (know-how) is shared in forums. Our findings suggest new factors, e.g., the use of linguistic memes and the pseudo-synchronous danmaku design, that may contribute to increased social interaction via online videos. Our work also sheds light on future designs for online video websites.

2 RELATED WORK

Compared to the traditional forum design, danmaku is different mainly at (1) building a "Pseudo-Synchronized" communication experience [67], where danmaku may make users feel like they are co-watching the video at the same time even though they can post danmaku comments at different times [49], and (2) being displayed anonymously [96]. In this section, we review literature on relevant factors that impact user participation and social interaction in online communities, e.g., synchronous/asynchronous communication, anonymity, and linguistic characteristics. However, prior work also found that both traditional forums [52, 79] and danmaku [13, 49] are used for knowledge sharing, where users posted and answered questions [49, 52] or shared opinions [79, 97]. Thus, we also review relevant literature on knowledge sharing in online communities. Drawing from the existing literature, we propose our hypotheses for comparing the two designs from a variety of perspectives.



Fig. 1. User interface displaying danmaku and forum comments on Bilibili.com. Forum comments are displayed in a linear manner below the video display in order of the time when the comments are posted. Danmaku comments are displayed along with particular segments of the video. In addition, Bilibili.com offers the following three modes that display danmaku on the screen: (1) Rolling danmaku, the default mode, where users' danmaku comments are positioned randomly on the video screen and fly from right to left; (2) Top danmaku, which centers the comments on the top of the screen; and (3) Bottom danmaku, which centers danmaku comments at the bottom of the video window. Users can select different display modes, colors, and fonts for their danmaku comments.

2.1 Synchronization and Anonymity in Online Communication

Providing synchronous communication media is predicted to improve user participation [66]. For example, in an online business-writing classroom, students generated a significantly larger amount of discussion when interacting with each other via the synchronous conference option [51]. It was also found that users wrote significantly more sentences in synchronous online discussions than in asynchronous discussions [33]. Yu et al. conducted a qualitative study to compare two alternative comment media, danmaku's Synchronous Overlay and Adjacent Scrollable, and found that the former promoted a stronger sense of togetherness [98].

Anonymity is also found to have a positive impact on user participation [26, 32, 40]. For example, Kilner et al. analyzed an online forum of practice for U.S. soldiers and found that removing anonymity options led to significantly fewer comments [40]. In a web forum for a basic undergraduate technology course, students who were anonymous were approximately five times more likely to provide critical suggestions than those who were not anonymous [32]. Through a scenario-based experimental study, researchers found that anonymous groups participated significantly more in

chatting than identified groups [26]. Given that anonymous danmaku creates pseudo-synchronous experiences, we developed the following hypothesis:

H1: Users send more danmaku comments than forum comments.

Anonymity not only provides a safe way to interact but also results in lack of accountability [57]. This loss of accountability results in an increased level of toxic disinhibition, consequently promoting impulsive, aggressive, and abusive behaviors [16]. According to Tucey's study, anonymous discussion can be of a lower quality than its counterpart; it can lead to flaming, rudeness, and less thoughtful contributions to the debate, because participants feel that they have less responsibility for their words [86]. On the contrary, a more revealed identity yields less swearing, less anger, more affect words, more positive emotion words, and less negative emotion words in comments [60]. Kilner and Hoadley observed that the prohibition of anonymous posts on a military professional education site almost completely eliminated negative comments [40]. Thus, we developed our second hypothesis:

H2: Danmaku comments are more negative than forum comments.

2.2 Collective Emotions in Online Communication

Prior work finds that negative comments may intensify online communication [23]. For example, one study compared anonymous and spontaneous Internet Relay Chat (IRC) channels with blogs or forums. It was found that negative comments resulted in more participation and prolonged the discussions both in IRC channels and blogs/forums [23].

Collective emotions refer to the same emotions shared by a large number of individuals for different reasons in an online or offline group [68], and collective emotions have been studied in the context of online chatting and forums where similar findings were discovered about negative comments [14, 23, 76]. For example, Chiniel et al. studied the BBC forum [14] and Tadić et al. examined the collective emotions in blogs and IRC [76]; both confirmed that negative emotions appeared in popular posts that received more comments.

Scholars studied users' motivations and practices of using danmaku and found that users took it as a channel for information-seeking and expressing emotions [49]. For example, people watched danmaku videos for entertainment (humorous comments), seeking resonance (the feeling of co-viewing with others), and information (videos' background or translation) [13]. However, overwhelming comments, insulting language, and conflicts among different user groups were also common in danmaku [44, 53]. Given the above literature, we developed the following hypothesis:

H3: Both danmaku and forum comments are more negative when more comments were posted to the video.

2.3 Linguistic Memes in Online Communication

Though there were very limited studies on danmaku, interesting findings about its language were revealed in early work. For example, it is found that Internet slang is widely used in danmaku, e.g., a popular slang word in danmaku, "hhhh," is an onomatopoeic word that imitates laughs [49]. Internet slang has been studied as one type of online linguistic meme.

A meme is defined as "an idea, behavior, or style that spreads from person to person within a culture—often with the aim of conveying a particular phenomenon, theme, or meaning represented by the meme" [20]. Through e-mail, instant messaging, forums, blogs, and social networking sites, memes are spread quickly and broadly among online users, which enables the Internet to effectively become a "meme factory" [56]. Memes have been employed in investigating cultural transmission, diffusion, and transformation, as a cultural unit or part of a culture [72, 90]. According to Dawkin's theory, the Internet meme can be a written text, image, joke, rumor, video, or website that is transmitted from one person to others [8, 42]. In western culture, scholars mainly focused

on analyzing the video memes (e.g., Hitler's reactions in the movie *Downfall*) and graphical memes (e.g., captioned photos that are intended to be funny, like "But That's None of My Business") [8, 24, 71].

Very few works studied linguistic memes, which are "units of language that encapsulate a core idea and that is transmitted, largely intact, among individuals—examples include slogans, sayings, metaphors and stories" [29]. Existing findings show that linguistic memes can help facilitate team management and coordination [18, 39, 69]. The initial findings about slang usage in danmaku [49] motivate us to apply both qualitative and quantitative methods to investigate memes in danmaku and forum comments. Prior literature suggests:

H4: Danmaku comments contain more linguistic memes than forum comments.

2.4 Knowledge Sharing in Online Communities and Social Networks

Prior studies found that users sent danmaku comments for knowledge sharing, e.g., explaining terminologies [47] and crowdsourcing captions [50]. Forums can be a public space for answering questions [52], engaging in debates, and exchanging opinions about various topics [79] on YouTube.

There are different genres of knowledge that vary, given different purposes of knowledge management [3, 94]. For example, according to the ownership, knowledge can be divided into individual knowledge and collective knowledge. Scholars have been using Brown's definitions of explicit knowledge and tacit knowledge [11] to differentiate ways of knowledge sharing [94] in virtual environments, e.g., in healthcare systems [1, 74], e-government [61], and social media [63]. Thus, we also adopt Brown's definitions of knowledge to examine user interactions through the two types of comments.

More specifically, explicit knowledge is referred to as "know-what" knowledge and expressed in words, numbers, or symbols, and stored in databases, memos, notes, documents, and so on. This type of knowledge is formalized and codified, thus it is easier to identify, store, retrieve, and communicate [92]. Tacit knowledge is referred to as "know-how" knowledge. It can be defined as experiences, beliefs, values, intuitive feelings, mental models, skills, and observations in people's minds [17, 63]. Panahi et al. also discussed other properties of tacit knowledge, including "highly individual and personal," "transferred through conversation and narrative," and "context-specific" [63]. The key to acquiring tacit knowledge is through sharing experience or people's thought processes [43]. Abidi et al. regarded healthcare practitioners' innate skills, experiences, and intuitive judgment as tacit knowledge, and they found that social media and online discussion forums can promote sharing of such tacit knowledge [1]. Happer et al. found that on social Q&A sites, users asked informational questions and conversational questions that aimed to simulate discussions for sharing expression and opinions, promoting tacit knowledge sharing [28]. Panahi et al. claimed that characteristics of social media, e.g., user-generated content, peer-to-peer communication, and multimedia-oriented, can support tacit knowledge sharing [63].

Given that terminologies [47] and captions [50] on danmaku are more about "what" (explicit knowledge) and debates and opinions found in forums [79] are more about "how" (tacit knowledge), we develop the following hypotheses:

H5a: More explicit knowledge is shared than tacit knowledge in danmaku comments.

H5b: More tacit knowledge is shared than explicit knowledge in forum comments.

2.5 Social Presence Theory

Danmaku and traditional forum designs for online users to share their comments are meant to promote social interactions and online users' social presence, which is defined as humans' perceptions in social environments [25, 73]. Tu et al. also explained social presence as the degree of

feeling, perception, and reaction of being connected by the computer-mediated communication (CMC) to another intellectual entity [84]. Prior work investigates different factors that can contribute to increased social presence in online communities [10]; intimacy and immediacy are found as two key factors [36, 73, 83].

In the physical world, intimacy is influenced by factors such as physical distance, eye contact, smiling, and personal conversation [5], and immediacy can be a psychological distance between communicators, which is represented via eye contact, vocal expressiveness, physical proximity, appropriate touching, leaning toward a person, gesturing, and so on [73]. Greater intimacy and immediacy can improve social presence [25].

In online communities, intimacy and immediacy can be decomposed into three sub-aspects: social context (e.g., tasks, privacy, topics, recipients/social relationships, etc.), online communication (e.g., the exchange of thoughts, messages, or information online), and interactivity (a two-way exchange that promotes immediate response) [81, 82]. It was also found that the interactivity-related strategies, e.g., timely response to CMC messages and use of stylistic communication styles, had a positive impact on the reported social presence [84]. For example, figurative language helps create a sense of closeness and intimacy between speakers and listeners [19]. A survey study also tested that the sense of social presence (e.g., a feeling of human contact, sociability, warmth, and sensitivity) on Twitter was shaped by immediacy-related characteristics (e.g., immediacy of feedback) and intimacy-related characteristics (e.g., perceived privacy) [27].

Danmaku created a co-watching experience, which is suggested to promote stronger social presence [99]. Scholars advise researchers to further examine the impact of the new danmaku design on social presence [54, 70]. We collected danmaku and forum comments and applied both quantitative and qualitative methods to examine the patterns of user participation, collective emotions, language style, and knowledge sharing between the two commentary designs. Our findings will contribute insights to the advancement of social presence theory in online communities.

3 METHOD

We collected archival data from Bilibili.com and annotated the collected comments in terms of the type of knowledge sharing, then we performed both quantitative and qualitative methods to test our hypotheses.

3.1 Data Collection and Processing

We used the Bilibili official API to crawl both danmaku and forum comments. In Bilibili.com, there are six popular genres of videos: anime, dramas, games, lectures, sports, and TV shows. For each of the six genres, we selected five popular videos that were uploaded recently. To make a fair comparison between the two types of comments, for each video, we analyzed the two datasets in the same time frame. The data collection was conducted between March and May of 2017. Finally, we collected 38,399 danmaku comments and 16,414 forum comments from 30 videos. Table 1 shows basic information regarding the videos and comments according to the genres. Each collected forum comment is provided with the real user identifier that is used to log in to the website, but each danmaku comment contains a pseudonymous identifier of the comment creator.

3.2 Data Analysis

To test the proposed hypotheses, we performed statistical tests to examine the characteristics of danmaku comments and forum comments. For example, when comparing the level of user participation in sending danmaku and forum comments, we conducted the t-test if the test statistic followed a normal distribution; otherwise, we employed the Wilcoxon-Mann-Whitney test. We applied the Pearson's product-moment correlation method to test the relationship between comment

Table 1. Basic Information Regarding the Videos and Collected Comments According to the Six Genres

Genre	Video in Total	Average Video Length (mins)	Average Viewers	Danmaku Comments in Total	Forum Comments in Total
Anime	5	20	32,620	9,163	2,518
Drama	5	28	18,997	6,591	4,806
Game	5	15	233,974	7,143	1,684
Lecture	5	24	194,650	3,541	4,581
Sports	5	21	201,507	4,294	1,658
TV show	5	22	36,757	7,667	1,167

sentiment score and user post frequency, and ran the Chi-square test to examine the interaction between the type of knowledge sharing (i.e., explicit and tacit) and the type of comments (i.e., danmaku and forum).

We also conducted content analysis to gain a better understanding of users' commentary behavior, including: what danmaku comments active users made; what language patterns emerged in danmaku comments; and how knowledge was shared in danmaku and forum comments.

3.2.1 Sentiment Analysis. To conduct sentiment analysis, we used a tool called SnowNLP, which has been applied for sentiment analysis of microblog comments in Chinese [62]. Microblog comments, danmaku comments, and forum comments are all oral and short text. Each comment is an input and will be rated a positive sentimental score from 0 to 1. The comment is more positive if its score is closer to 1 and more negative if closer to 0.

3.2.2 Linguistic Memes. To investigate features of linguistic memes used in danmaku comments and forum comments, we searched linguistic memes on two popular encyclopedia websites, i.e., Baidu Baike [6] and Moegirlpedia [55]. We combined the linguistic memes from the two sources into a comprehensive collection of 1,134 linguistic memes in total. For example, “GJ” (referring to good job) and “KY” (the abbreviation of “空がめない” in Japanese meaning inconsiderate). To pre-process the comment data, we applied a popular Chinese tokenizer, Jieba, which allows the upload of a self-developed library. When analyzing the data, we took the meme collection as the self-developed library that successfully avoided Jieba tokenizer from separating linguistic memes into separate tokens. Then, we counted the frequency of linguistic memes used in danmaku comments and forum comments, respectively.

3.2.3 Annotation of Knowledge Sharing. To understand the type of knowledge shared in danmaku comments and forum comments, we adopted the definitions of explicit and tacit knowledge [11] to annotate the comments.

For example, the fact-based comment “The BGM (background music) is Victory” and the terminology definition comment “Islam’s stone punishment is burying a person’s lower body into the soil and then killing the person by throwing stones” were annotated as explicit knowledge sharing. Comments that described users’ personal experience or opinions, e.g., “The cell phone signal of China Telecom works well in the dorms of my university,” and “The commentator [of the ice hockey game] is too subjective! He is not professional,” were annotated as tacit knowledge sharing.

Initially, we randomly selected 500 danmaku comments and 500 forum comments and asked two coders to independently annotate them into three categories: explicit knowledge, tacit knowledge, or non-knowledge. For each comment, if both of the two coders annotated them into either explicit

or tacit knowledge, then we affirmed it was knowledge; otherwise, it was non-knowledge. Then, we calculated two coders' agreement on explicit knowledge and tacit knowledge. The kappa value is 0.86 for danmaku knowledge and 0.87 for forum knowledge, both of which show substantial agreement ($0.61 \sim 0.80$) [89]. Finally, a third coder resolved the disagreement with the first two coders together using the "majority rule" approach.

4 FINDINGS

In this section, we present our quantitative results that address the proposed hypotheses along with qualitative analyses.

4.1 User Participation

There were 20,887 unique users involved in 38,399 danmaku comments and 10,148 unique users involved in 16,414 forum comments.

To test the first hypothesis, we applied statistical methods to compare the count of comments, the number of unique users, and users' post frequency in danmaku and forum comments for the 30 videos. We also applied qualitative analysis to present how active users used the two comment features.

4.1.1 Total Comments. First, we applied the Shapiro-Wilk's method to test the distribution of danmaku comment counts and forum comment counts for the 30 videos. Neither of the samples followed a normal distribution (the counts of danmaku comments: $N = 30$, $W = 0.68$, $p < 0.001$; the counts of forum comments: $N = 30$, $W = 0.59$, $p < 0.001$). Thus, we applied the Wilcoxon-Mann-Whitney test to compare the counts of danmaku and forum comments. The counts of danmaku comments ($N = 30$, $Mean = 1,280$, $SD = 1,200$) were significantly larger than the counts of forum comments ($N = 30$, $Mean = 547$, $SD = 797$, $V = 400$, $p < 0.01$). **(H1 supported)**

When comparing user participation within each genre, game, and TV show, videos seemed to attract more danmaku comments, according to Table 1. Only lecture videos had relatively less danmaku comments than forum comments.

4.1.2 User Counts and Post Frequency. Similarly, we applied the Shapiro-Wilk's method to test the distribution of the numbers of unique users in danmaku comments ($N = 30$, $W = 0.82$, $p < 0.001$) and the numbers of unique users in forum comments ($N = 30$, $W = 0.77$, $p < 0.001$) for the 30 videos. Neither followed a normal distribution. Therefore, we applied the Wilcoxon-Mann-Whitney test to conduct the comparison. The result showed that the numbers of unique users involved in danmaku ($N = 30$, $Mean = 707$, $SD = 527$) were significantly larger than those in forum comments ($N = 30$, $Mean = 343$, $SD = 366$, $V = 392$, $p < 0.01$).

We also compared users' post frequency in danmaku and forum comments. Due to unequal sample sizes and unequal variances for the two kinds of comments, we conducted Games-Howell tests [46] for post hoc pair-wise comparisons. The number of danmaku comments posted per user ($N = 20,887$, $Mean = 1.91$, $SD = 0.84$) was significantly larger than the number of forum comments posted per user ($N = 10,148$, $Mean = 1.45$, $SD = 0.42$, $t = 2.72$, $df = 44$, $p < 0.01$).

4.1.3 Unique Active Users in Danmaku. There were not only more comments but also more users active in danmaku than forums. To address why there were more active users in danmaku, we reviewed the top 20 active users in both danmaku and forums, respectively, to examine how they made comments. Interestingly, the active danmaku users conducted one or two functions constantly in their comments.

We identified four major groups of active users that emerged as a result of the unique interaction design of danmaku, i.e., overlaying comments on video displays. They include video caption providers, plotters, community-norm regulators, and parasocial commentors.

First, caption providers, who unofficially translate foreign languages to Chinese using danmaku comments, formed the major active user group. In danmaku, they are called “Caption-Kun” (“Kun” is a respectful name in Japanese). Interestingly, we found that, sometimes, multiple users collaboratively created Chinese captions by posting the danmaku comments. For example, an active Caption-Kun wrote 51 comments in a Norwegian TV play, among which 48 comments were captions, but the user did not finish translating the whole video. After many other users called for “Caption-Kun” by sending danmaku comments, such as “Caption-Kun, please come,” “Ah, I can’t understand [the language],” and so on, a second Caption-Kun showed up and finished creating the rest of the video captions. Both caption providers positioned their danmaku comments at the bottom of the screen, where official video captions were displayed typically. This has been a norm for video caption providers to follow. There are two types of captions: Closed captions are a text version of the spoken part of a video; and explanatory captions explain the visual or audio content of a video. Most Caption-Kun users seemed to make closed captions. Some of them also provided explanatory captions. For example, in a Japanese drama named *The Solitary Gourmet*, there were 105 users that posted danmaku comments to explain what the food was synchronously with the video view.

Second, plotters are the users who watch the same video more than once and send hints of the forthcoming plots. For instance, a game video user posted 43 comments on two different days. In the second day’s comments, he forecasted plots using danmaku comments, such as “High-energy reaction ahead!!!” (i.e., the following plot is very exciting), “High-energy reaction ahead, please wear a helmet!!!” (i.e., the following plot is very exciting and intense, please be prepared mentally), “Tut tut, see the end from here” (i.e., the end can be guessed through this plot). These plotters are different from spoilers. They don’t disclose detailed plots in comments but provide hints, which make videos more interesting and attractive. It is also time-saving for the users who are seeking specific information in videos, e.g., scientific lectures.

Third, community-norm regulators are those users who try to maintain the danmaku posting norms. For example, one active user, who posted 39 comments, was devoted to promoting polite language in danmaku communities. He posted: “please report this user who posted danmaku in yellow” (the yellow danmaku user made a statement that discredited women). The down arrow was used to indicate who the user was. Another active user with 34 danmaku comments sent: “Everyone reported the meaningless danmaku at the bottom [of the video screen]” (danmaku comments at the bottom of the screen usually cover captions).

In addition to the above typical user groups, there was another group of active users who exhibited parasocial interactions. Parasocial interaction (PSI) is defined as “an imaginary social relationship, an imaginary friendship, an illusion of face-to-face relationship, and an interpersonal interaction between the media user and the consumed media” [38]. For example, a user sent 40 danmaku comments in an online game competition video. These comments revealed that the user assumed the roles in the game himself/herself and made an imaginary conversation. For example, the user commented, “Childe: Beating you is a piece of cake,” “Dio Ye: God knows what happened to me,” and “Kris: Folks, please get your eyes checked with an ophthalmologist” (Childe, Dio Ye, and Kris are all roles in the game). However, such parasocial users rarely appeared.

4.2 Sentiment Analysis

4.2.1 Sentiment of Danmaku and Forum Comments. First, we employed the Shapiro-Wilk’s method to test the distribution of the sentiment scores of two groups of comments. Neither of

the samples followed a normal distribution. Thus, we applied the Wilcoxon-Mann-Whitney test to compare the sentiment scores of forum and danmaku comments. The sentiment of danmaku comments ($N = 38,399$, $Mean = 0.58$, $SD = 0.27$) were significantly more negative than the sentiment of forum comments ($N = 35,488$, $Mean = 0.6$, $SD = 0.34$) ($V = 6.35 \times 10^8$, $p < 0.001$). (**H2 supported**)

4.2.2 Active Users Posting Positive Comments in Danmaku. We further tested the correlation between sentiment score and user participation by applying the Pearson's product-moment correlation method. For each comment, the value of user participation was calculated by the number of comments each user sent. In danmaku, the sentiment variable had a positive correlation with the user participation variable ($t = 9.95$, $df = 38,397$, $p < 0.001$), which suggests that active users tend to send positive anonymous comments. However, in forum comments, there was no significant correlation between the sentiment score and the user participation ($t = 1.52$, $df = 16,412$, $p = 0.130$).

In danmaku, we observed how active users sent positive comments and non-active users sent negative comments. Also, active users tended to express their emotions. For example, active users sent numeric characters such as “2333” and alphabetical characters such as “hhhhh” to express their happiness. They also posted the same comments repeatedly or typed longer comments to express stronger emotions, e.g., “Ah ha ha ha ha ha ha ha ha,” “Oh my god ha ha ha ha ha ha ha ha ha,” and “Holy crap, laughing my fat ass off.”

It was interesting to find that the most active user wrote 120 similar danmaku comments to express his love to certain movie characters or happiness when watching a drama video, e.g., “_yoyo_,” “_cp_,” “___. Interestingly, the top two and top three active users also used many comments with underlines in the same videos, e.g., “_William __ ó,” “ó__ ó” to mimic a smiling face.

In a historical drama video, we also observed another type of positive comment from several active users. One user introduced the history background and complicated relationships among the characters in the drama, e.g., “Paul 1’s two wives were German,” “Ye 2’s grandson Alexander 1’s wife was Princess Amalia’s daughter.” Another active user also made positive comments on this drama but was more focused on the plots, e.g., “The son is handsome, not like his father!,” “This video is great, better than many domestically produced plays,” “True love, truly envy.”

On the contrary, non-active users often sent negative comments to show their disagreement, aversion or anger to the plot, a viewpoint, or a person in the video. For example, they posted “I’m gonna throw up [because of the extreme sports],” “What the hell was the goalkeeper doing???,” “The presenter is so terrible and subjective, he doesn’t even know ice hockey,” and “I will never buy Samsung, garbage cellphone!” The other negative comments showed users’ dissatisfaction to other bad danmaku comments, e.g., “where is your politeness, bottom comment (refers to the user who sent danmaku comments to the bottom of the screen, obscuring the subtitles),” “Warning: don’t reply! do not reply!” (one user reminded other users to follow the rule in danmaku), and so on.

4.3 Collective Emotions

In forums, when users posted comments, a conversation was made within each discussion thread where different users can reply to each other. On the contrary, when users sent danmaku comments, they were not able to directly reply to another user’s comment as all comments were anonymous without user identifiers or usernames. Users typically commented on the same segment of the video in danmaku to engage in a discussion of a “common” topic defined by that certain video’s scenes. In short, forum comments were structured by discussion threads, whereas danmaku comments could be structured by the timeline of the videos.

There were 7,804 initial forum comments, among which 2,025 received replies and formed discussion threads. Referring to the method in Reference [93], where average positivity or negativity sentiment was used for threads sentiment analysis, we calculated the participation (count of forum comments) (Mean = 5.25, SD = 10.54) and the average sentiment score (Mean = 0.61, SD = 0.23) in each forum thread. A Pearson test was conducted between the two variables. There was no significant correlation between the participation and the sentiment in forum comments ($t = 1.06$, $df = 2,023$, $p = 0.29$).

To calculate the participation and average sentiment scores in danmaku comments, we standardized the timeline of each video and divided it into 10 time windows (about 2.6mins for each time window) and 100 time windows (about 0.26min for each time window), respectively. Then, we calculated the participation and the average sentiment score in each time window. A Pearson test was conducted between the two variables. When the video timeline was divided into 10 equal windows, there was a significant correlation between user participation (Mean = 116.36, SD = 132.58) and sentiment (Mean = 0.56, SD = 0.07) of the comments ($t = 3.79$, $df = 328$, $p < 0.001$). The correlation coefficient was 0.205. When the video was divided into 100 equal windows, there was also a significant correlation between user participation (Mean = 14.08, SD = 18.35) and sentiment (Mean = 0.56, SD = 0.12) of the comments ($t = 5.09$, $df = 2,712$, $p < 0.001$). The correlation coefficient was 0.097. Namely, the danmaku comments were more positive when more participation was involved. **(H3 not supported)**

Figure 2 shows the mean of the sentiment score and total user participation (count of danmaku comments) for each video. For example, with the Game videos, e.g., Game_1, Game_2, Game_4, and Game_5, it could be observed that more participation was related with positive comments. The same relationship can also be observed in Lecture, Sports, and TV show. There were anomalies in some videos, but the overall trend is illustrated. To further understand why these many individual users created positive comments when there was heated communication, we case-studied sample comments in these videos and discovered interesting user behaviors.

For instance, Game_1 displayed professional players playing a computer game. Some users praised a game player for doing a great job, which attracted more users to comment to that particular video segment. For example, they posted “Very excited,” and “Little DVA did a very good job.” Then they started to discuss what good strategies were used in the game and they even asked about the BGM (Background Music) of the video, e.g., “He tactfully pinned the enemy 233333.” Similarly, in Game_2, users showed their excitement by sending danmaku comments, such as “The games whenever you are in can be made into stories!” and “Ah ah ah ah, this is very cute!!!” The atmosphere reached the peak when they shouted and cheered over the victory by commenting “Hero certification!” and “Monster Hunter!”

As another example, in lecture_1, an educational video entitled “*China Eye Plans to Shock the World, Hawking Has Repeatedly Warned to Stop, Jealousy?*,” users actively participated in the topic of searching for extraterrestrial civilizations. It triggered diverse and rational discussions. For example, they posted “I hope that everyone need to philosophize about the current technologies,” “Higher the civilization, less the possibility of violence,” and “If Aliens can reach the Earth, their technologies are advanced than ours.” Lecture_3 was another video that compared different cell-phones. The video introduced a new Sony product that brought about many good evaluations. For example, they commented “The front face [of Sony’s phone] is pretty,” “I like it, the price is very nice, lower than Huawei,” “The frame numbers [of the camera] is pretty high!,” and “I still prefer Sony.”

As shown in Figure 1, the majority of danmaku comments (90.06%) were randomly positioned on the screen using a default setting; only active users who had the right to position comments at a certain area on the screen, which resulted in 9.94% danmaku positioned at a customized area,

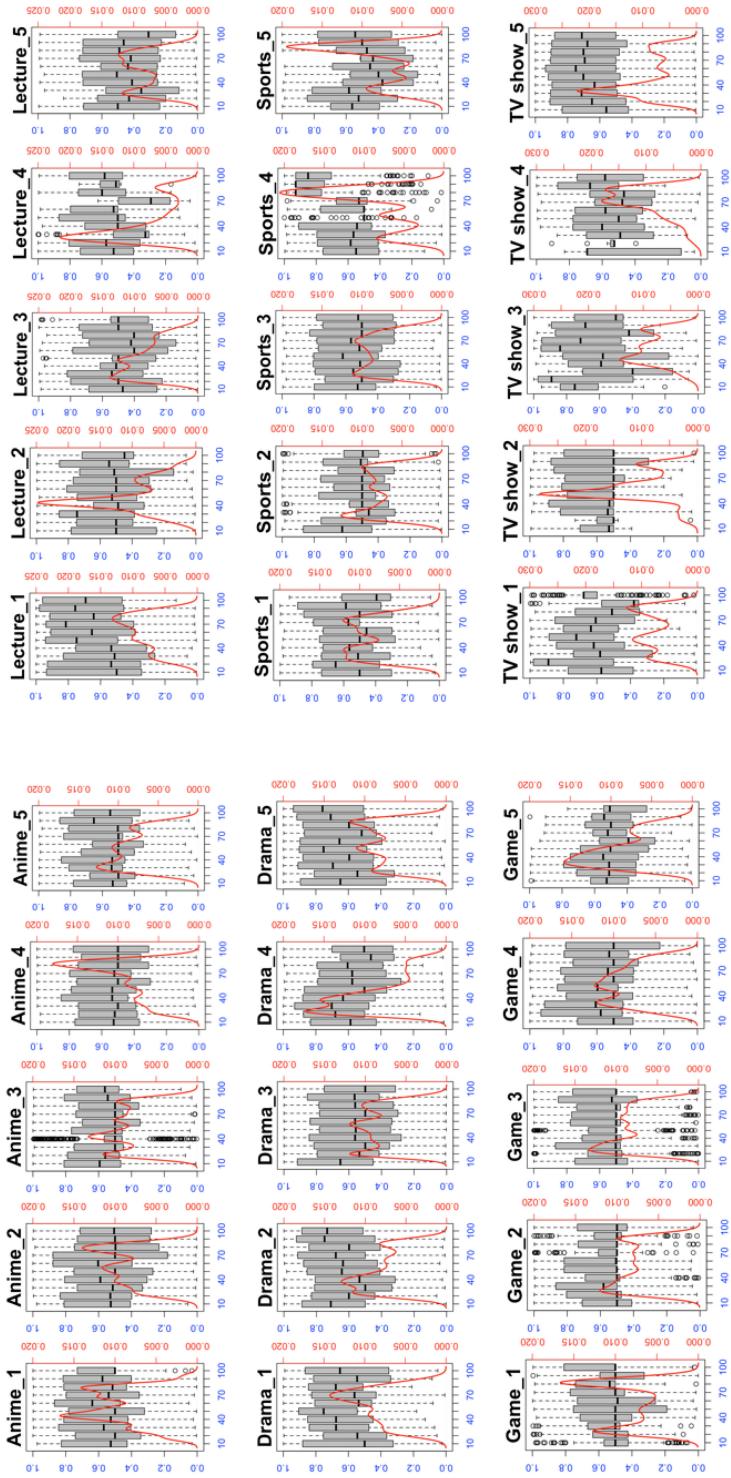


Fig. 2. Sentiment and Participation. The X-axis shows the video timeline segmented to 10 windows; the left Y-axis is the sentiment scores; and the right Y-axis is the participation. The plots illustrate the sentiment distribution (grey box) and participation (red line) along with the video timeline.

e.g., the top of the screen, the bottom of the screen, and so on. It was interesting to find that 124 active users created clusters of danmaku comments by customizing the positions of the comments. These clustered danmaku comments shared the same emotions and heated the communication. For example, in the video Sports_5, a football game between China and South Korea, one active user sent 32 similar danmaku comments—“If miracle has color, it must be Chinese Red!”—to express his happiness towards China winning the football game at either the top or the bottom of the screen. Later, 25 other active users joined in pleasantly flooding the screen by following the same customization. Sending danmaku comments to specific areas also had other usage, e.g., helping to announce the sports game, showing one’s opinion, translating captions, and so on.

4.4 Linguistic Memes

4.4.1 Memes Used in Danmaku and Forum. After processing the comments, 364 linguistic memes were identified in the 38,399 danmaku comments, and 337 linguistic memes were found in the 16,414 forum comments. We compared the number of linguistic memes used in each comment. Due to unequal sample size and unequal variances for the danmaku comments and forum comments, we conducted Games-Howell tests for post hoc pair-wise comparisons. The results showed that the number of linguistic memes used per danmaku comment ($N = 38,399$, $Mean = 0.14$, $SD = 0.49$) was significantly larger than the number of linguistic memes used per forum comment ($N = 16,414$, $Mean = 0.06$, $SD = 0.33$, $t = 21$, $df = 43,960$, $p < 0.01$). (**H4 supported**)

4.4.2 Language Patterns of Memes in Danmaku and Forum. We further explored the language patterns of linguistic memes in both comments. It appeared that linguistic memes in danmaku were often used to express emotions or opinions related to the video content. For example, users took special characters that were easier to type, e.g., “233333” (to express laugh out loud), “hhhhh” (to imitate laugh sounds), and “wwwwwwwww” (to show laughs). It is found that danmaku users entertain each other to meet their psychological needs, and they are not concerned with whether these emotions or opinions can create actual utility (e.g., persuade others) [34].

We also found that several linguistic memes were used to support interaction among the users. These linguistic memes tend to be brief and flexible. For example, to ask other users questions related to the videos, users typed “BGM” (background music) or “OP” (Opening Song); to invoke a call for action, they commented “If magic has colors” or “Caption group” (call for language translation); to provide information, they commented “[There is] high-energy reaction ahead” (spoilers) or “Progress bar” (to indicate the remaining time); to show one’s own opinions to other users or debate with others, they entered “1” or “+1” (agree with previous comments). These linguistic memes were used to construct a norm in the danmaku community.

4.4.3 Cultural Background of Linguistic Memes in Danmaku and Forum. When exploring the cultural backgrounds of linguistic memes in danmaku and forum comments, we found that popular linguistic memes (used more than 40 times) used in forum comments mainly emerged from four different cultural backgrounds, including ACG (Anime, Comic, and Games) culture, used in some subcultures of Greater China [95], Chinese characters, foreign language, and pictogram. For example, the linguistic meme “The danmaku on the left side is too thin” was generated from one of the most famous and successful Japanese anime series, *Mobile Suit Gundam*, which has been produced since 1979. In an anime, it was used to describe the weak firepower in fights. Through several years’ propaganda, it came to describe the small amount of danmaku comments. As another example, “6666” is the homonym of a Chinese character (“溜”) that was used for praising someone for their superb skills or professional performance. “...Jiang” originates from Japanese “ちやん,” which is often added as a suffix to girls’ names to express geniality. “QAQ” is a pictogram that mimics a crying face.

Similarly, the most popular linguistic memes used in danmaku comments emerged from the ACG culture, Chinese characters, foreign languages, and pictograms. However, besides these cultures, linguistic memes in danmaku also stemmed from literature, films, and television programs, and social events also took an important place in danmaku comments. For example, “FFF Group” emerged from the Japanese light novel *Baka and Test*, which reminded people not to show off their romantic relationships in front of single persons; “German orthopedics” came out of a social rumor that described the love between sisters and brothers. According to the result, the cultural backgrounds of linguistic memes in danmaku comments were more diverse than in forum comments.

4.4.4 Functional Features of Memes in Danmaku and Forum. Through qualitative analysis, we found that linguistic memes in both danmaku comments and forum comments served several functional purposes. First, linguistic memes in danmaku comments can help label users, where “Caption-Kun” was used to label users who contributed video captions via sending danmaku comments. Owning the same group identity promoted their collaboration. For instance, in a Norwegian drama, we found that two Caption-Kuns generated captions one after another in a collaborative manner. Next, memes in danmaku comments were also used to make suggestions to other users for certain actions. For example, the meme “If miracle has color...” worked as a trigger that informed users to send danmaku comments with a specific color to overlay the video content. Moreover, in forum comments, users used linguistic memes to express their standing. For example, in a video entitled “As a women, I feel really sorry for it,” there were 24 users who used the meme “The Qing Dynasty is died” in their forum comments as a way of showing their support to feminism.

4.4.5 Text Length. To investigate how online linguistic memes are used in danmaku comments and forum comments, we first compared the text length of danmaku comments and forum comments. Due to unequal sample sizes and unequal variances of comment length for the two kinds of comments, we then conducted Games-Howell tests for post hoc pair-wise comparisons. The result showed that danmaku comments ($Mean = 9.33$, $SD = 39.1$) were significantly shorter than forum comments ($Mean = 45.23$, $SD = 4,920$, $t = 65.6$, $df = 17$, $p < 0.001$).

We also conducted correlation tests between the count of comments and the length of comments. For danmaku, the comments were significantly shorter when there was more participation ($t = -7.48$, $df = 2712$, $p < 0.001$). But for forum, the comments were significantly longer when there was more participation ($t = 4.05$, $df = 2023$, $p < 0.001$). It is still worth noting that the average length of a danmaku comment is 9.33 words, and the average length of forum comments was 45.23, which is far shorter than the word limit of 220 words of danmaku.

4.5 Knowledge Sharing

4.5.1 Explicit Knowledge and Tacit Knowledge. After annotating the comments, we identified 667 cases of knowledge sharing in danmaku comments, out of which 463 (69.42%) cases were explicit knowledge and 204 (30.58%) cases were tacit knowledge. In forum comments, we identified 734 cases of knowledge, where 212 (28.88%) cases were explicit knowledge and 522 (71.12%) cases were tacit knowledge. Table 2 presents the distribution of explicit and tacit knowledge for different video genres in danmaku comments and forum comments.

A Chi-square test of independence was calculated to compare ways of knowledge sharing in danmaku and forum comments. Danmaku and forum were significantly different in the way of sharing knowledge, i.e., explicit knowledge was shared more in danmaku comments and tacit knowledge was shared more in forum comments ($X^2 = 228.33$, $df = 1$, $p < 0.001$). Further, we did Wilcoxon-Mann-Whitney tests to compare shared explicit and tacit knowledge for danmaku comments and forum comments individually. The results showed that (1) danmaku comments shared significantly more explicit knowledge ($N = 30$, $Mean = 15.43$, $SD = 21.11$) than tacit knowledge

Table 2. The Distribution of Explicit and Tacit Knowledge in Different Video Genres

Genre	Danmaku Knowledge				Forum Knowledge			
	Explicit		Tacit		Explicit		Tacit	
Anime	18	55%	15	45%	57	80%	14	20%
Drama	190	84%	36	16%	91	27%	246	73%
Game	34	40%	50	60%	5	56%	4	44%
Lecture	62	63%	37	37%	30	14%	180	86%
Sports	97	73%	35	27%	20	51%	19	49%
TV show	62	67%	31	33%	9	13%	59	87%
Total	463	69%	204	31%	212	29%	522	71%

($N = 30$, $Mean = 6.8$, $SD = 7.69$) ($V = 363$, $p < 0.01$) (**H5a supported**); (2) forum comments shared more tacit knowledge ($N = 30$, $Mean = 19.33$, $SD = 53.16$) than explicit knowledge ($N = 30$, $Mean = 7.85$, $SD = 18.39$) ($V = 115.5$, $p = 0.502$), but the difference was not significant. (**H5b not supported**)

We also examined the knowledge type distribution in different genres in danmaku comments and forum comments. From Table 2, in Drama, Lecture, and TV show genres, explicit knowledge was shared more than in danmaku comments, but tacit knowledge was shared more in forum comments; in Anime and Sports, both danmaku and forum possessed more explicit knowledge than tacit knowledge; in Game videos, more tacit knowledge was shared than explicit knowledge in danmaku comments and very little knowledge was shared in forum. All genres had significant Chi-square test results except the Game genre ($X^2 = 0.27$, $df = 1$, $p = 0.606$).

4.5.2 Knowledge Sharing in Danmaku.

There were various types of explicit knowledge and tacit knowledge shared in danmaku comments.

More specifically, we observed explicit knowledge sharing on a variety of topics, including: (1) Natural Science, e.g., “[This is a] high-dimension space” (anime), “Sleeping soft tissue fluid comes from the kidneys” (lecture), “Electromagnetic waves could be transmitted in vacuum” (lecture); (2) Social Science, e.g., “The race does not determine the culture, but the culture determines the attributes of human beings” (TV show), “England is a united kingdom, it indeed consists of four countries, not four districts” (TV show), and “The nature of comedies is satire” (TV show); (3) Technology, e.g., “[The pictures] whose visual are round were taken by wide-angle lens” (sports), “This is not a dynamic wallpaper, it’s called Live Photos” (lecture), and “The signals of the three telecom operators might be different even at the same place, so the same place can’t be the control condition of the test” (lecture); and (4) Other Information, e.g., “The lady in blue cheongsam is an actress in the movie Mr. Donkey” (drama), “The background music is River Flows in You” (drama), and “[The boxer] with blue gloves is from China” (one user asked which boxer was from China) (sports).

For tacit knowledge, we observed (1) Opinion, e.g., “It’s been proved as a norm that commentary is a personal live broadcast but not a television program relay, so it will come along with subjective emotions” (sports), “In order to fully show the proper respect and manner to one’s country, everyone from any country should take off their hats during national flag raising” (TV show), and “Respect women but not support the materialistic feminism, women should be protected” (drama); (2) Experience, e.g., “The dubbed laughter here serve as a purpose to enhance the voice effect on this program, this is certainly a talk show 눈_눈 (an emoji to express speechless)” (TV show), “Personally, I prefer the home button on the Samsung phone” (lecture), and “[This was] made by Keynote. Those pages were easy to make by Magic Move” (lecture); and (3) Community-based, which means specific knowledge (rules, norm) in a danmaku context, e.g., “Please keep in mind

that it is extremely disrespectful to mention other uploaders” (uploader is who uploaded videos) (game), and “Folks, please actively report the insulting comments” (lecture).

4.5.3 Case Studies of Knowledge Sharing in Danmaku and Forum. To understand if danmaku and forum comments shared knowledge differently, we selected comments that shared knowledge regarding the same topics in both danmaku comments and forum comments of a video.

For example, in the video, entitled “*As a women, I feel really sorry for it,*” the topic of feminism was commented on in both danmaku and forum. The video was made by clipping several famous feminist movies or dramas and triggered heated discussion among users.

In danmaku comments, the major topic was to define “feminism.” Many users held the same view that “feminism meant equal rights between men and women, not femdom.” Besides the discussion of “feminism,” users also commented about this short video. Users shared the names of the movies or dramas, e.g., “[the movie shown] just now is Blind Mountain (a Chinese movie),” or the names of actresses, e.g., “This is Yuanyuan (a Chinese actress).” They also introduced the stone punishment that was used to punish women in Iran, e.g., “[This is] Iranian Stoning Penalty.” Several users also recommended other related movies or dramas in comments, “Please add Malena (a famous Italian movie that is also about feminism).” Interestingly, users also shared where the video title “*I feel really sorry for it*” came from and came up with three different answers. For example, one user thought that it came from a movie “*Memories of Matsuko*.” Though they did not have an agreement, other users received more perspectives by reading the danmaku. We also noticed that users addressed each other directly in several danmaku comments, i.e., “Greetings to the previous user [who made the last danmaku comment], the women in cheongsam is [the role] in the movie Mr. Donkey,” to answer questions that were posed by a previous user.

However, in forum comments, we observed that the topics were extended from defining feminism to a variety of other topics. For example, users commented in the forum regarding marriage, DINK (Double Income No Kids), females in politics, female discrimination in the workplace, equality of men and women in China, and so on. Users shared more arguments (e.g., their own experiences, or laws) to demonstrate their opinions, and the arguments were longer than those in danmaku.

Another example was the China Eye Plans (the biggest spherical radio telescope) video. In danmaku comments, users mainly discussed what FAST was used for and its scientific, ethical, and political issues in the exploration of outer space. In addition, users also shared their opinions about extra-terrestrial intelligence. It is worth mentioning that the users also shared popular science fiction, “The Three Body Problem,” and the “Dark Forest Law” in it—“Once be found [by each other], only one side can remain alive.” In forum comments, we found that the users tended to explain further about why China developed the FAST program and Hawking’s theory.

5 DISCUSSION

The unique contribution of our work is that we provide empirical evidence showing how danmaku was used differently from forum and how danmaku improved social interaction via online videos. More specifically, we examined both comments in terms of user participation (**H1**), comment sentiment (**H2**), collective emotions (**H3**), linguistic memes (**H4**), and knowledge sharing (**H5s**). In this section, we reflect on our findings, discuss theoretical contributions, propose new designs, and address our limitations.

5.1 Reflection on the Findings

5.1.1 Unique User Groups and Interaction using Danmaku. Anonymity encourages users’ early and continued participation [4], and the sense of security provided by anonymity can encourage

students to share their thoughts more freely [88]. Therefore, it is not surprising that there were more anonymous danmaku comments than user-identified forum comments (**H1**). Besides, participation within each genre was also compared between danmaku and forum. The results showed users' different commentary preferences for different genres of videos, which hasn't been revealed in previous studies related to video comments [22, 45]. For example, for the videos of Game and TV show, the danmaku feature could be considered for implementation to serve users' preference.

Also, we expanded the understanding of user participation by providing new empirical evidence and claims that more unique users engaged in danmaku and they were more actively posting danmaku comments. We further identified four groups of users, who made new types of interactions with online videos and their danmaku peers as a result of the unique user interaction design of danmaku.

For example, the pseudo-synchronous interaction of danmaku allows caption providers to create video captions by posting danmaku comments. In fact, there has been a large online community, called Fansub (fan subtitling) [21, 48, 80] who volunteer to translate foreign TV shows and programs. These online users could contribute directly to co-create video content by using the danmaku features. Plotters' comments not only raise other video users' awareness of the upcoming video content, but also catalyze users' interest to continue watching and find out the answers. Users who have parasocial interactions by posting imaginary story comments also enrich the content of the video [58]. Comments of community-norm regulators can alert users who violated the rules. These users collaboratively created a new culture of social interaction in online videos.

5.1.2 Active Users & Positive Danmaku Comments. Even though danmaku comments were significantly more negative than forum comments overall (**H2**), our results also showed that active users sent more positive and anonymous danmaku comments than less active users. However, there was no such association discovered in forum comments. A survey study reported that in virtual communities, reputation and reciprocity have a positive impact on posters' participation [30], however, our findings cannot be well explained by existing literature, which typically claimed anonymity resulted in more negative comments [40, 60, 86].

By examining collective emotions, we found that user participation was also positively related with the positive emotion in danmaku comments, which doesn't support our original hypothesis (**H3**). Through qualitative analysis, we observed that active users tended to send similar danmaku comments to express their emotions. Also, the unique danmaku design allowed active users to position comments in certain areas to support their expressions of different comments. Once a commenting style was created, it seemed that other users quickly adopted it.

It has been studied how to detect or analyze the sentiment in forum comments in video websites, e.g., YouTube [7, 87], MOOC discussion forums [93], however, our results expanded the understanding of collective emotions in danmaku and compared the differences between danmaku and forum. Our qualitative observation may help to explain this finding that active users contiguously sent a series of danmaku comments with the same sentiment at the same area. Similar to commenting styles, users created clusters of danmaku comments for strong emotions, especially for positive emotions.

5.1.3 Linguistic Memes in Online Communication. Our findings confirmed that danmaku had more linguistic memes than forum comments (**H4**). Several factors may be helpful to explain this finding. First, there is a big difference between the word limit of danmaku and that of forum comments. Users seemed to send very short danmaku comments (average word count is 9) even though they could technically send much longer comments (up to 220 words). The reason why users sent more short danmaku comments might be that by default danmaku comments fly from the right side of the screen to the left side of the screen; thus, such a linear display of danmaku comments

may not read easily if a comment is too long. Second, Wang analyzed the linguistic memes on China's biggest e-commerce website Taobao and found that the instant-messaging tool can facilitate online communication where memes are frequently used [90]. The language patterns of danmaku comments were very similar to that in online chat [2], where abbreviations, taboo words, short and simple sentences are frequently used. Danmaku design shared some commonality with Taobao's instant-messaging that it created an illusion that users were in a synchronous chat. This may further explain why danmaku had more memes than forum.

The large amount of memes that stems from diverse culture enable the danmaku comments to perform as a cultural melting pot, which allows danmaku to be a unique platform to study the process of cultural elements, including generation, development, and transmission.

Our findings also suggested certain functional features of linguistic memes in both danmaku and forum comments, including labeling users and cooperative users. First, labeling people to group them is one of the most essential requirements for cooperation. Previous research indicates that a super ordinary identity can resolve conflict [59]. For example, as a linguistic meme, "Caption-Kun" labeled users who provided captions for foreign language videos voluntarily and thereby constituted a group and created captions in a collaborative manner. Second, our finding also shows that linguistic memes facilitated coordination. For example, "The danmaku on the left side is too thin" is used to encourage other users to send more danmaku comments.

5.1.4 Complementary Knowledge Sharing. We applied Brown's definitions of explicit knowledge and tacit knowledge to differentiate ways of knowledge sharing [11] in online video websites. The findings partially supported our hypothesis regarding knowledge sharing on danmaku (**H5s**).

Our finding—that traditional forum comments involved more tacit knowledge sharing—was aligned with the prior literature [28, 63]. However, interestingly, danmaku—as a new social commenting feature—promoted explicit knowledge sharing instead of tacit knowledge sharing. These two comment features provide venues for knowledge sharing in a complementary manner on video websites.

Previous studies regarding the impact of asynchronous and synchronous online communication on knowledge sharing may be helpful to understand the finding. For example, Im and Lee demonstrated that synchronous communication could not develop into more serious learning stages beyond socialization, whereas asynchronous discussions were more topic-related and yielded more discussion about the posted topics [33, 37]. If we examine the data more closely, then according to Table 2, more explicit knowledge sharing seemed occur in video genres such as drama and sports, and much less explicit knowledge was shared in games and anime videos. In future work, we plan to test if users shared knowledge differently when commenting on different video genres.

5.2 Theoretical Implications

Our findings contribute to the development of social presence theory for social interaction via online videos in manifold. First, we identified new factors that influence intimacy and immediacy. As presented in our findings, there were more linguistic memes used in danmaku than in forum comments. The popular ones were more about expressing strong and positive emotions. They were used by active users and promoted positive emotion sharing and more user interaction. Prior work confirmed the impact of video and graphical memes in fostering social interaction. Our work added a new factor, i.e., the use of linguistic memes, that can help raise the level of intimacy. The observation that active users sent positive danmaku comments to certain parts of the videos heated user participation. It is suggested that allowing users to position danmaku on a certain area of the video display for a particular segment of the video enables immediacy, which in turn promoted social interaction among online users.

We attribute the discovery of these new factors to the unique design of danmaku, as our findings showed that danmaku comments were much shorter and shared more explicit knowledge in concise language. Because danmaku comments fly from the right to the left in one line, there was limited content to be displayed in a short period of time. Such designs might explain why memes were used and the customization behavior of active users.

These new relationships might also help explain why some of our hypotheses were rejected. According to the existing factors of social presence theory, anonymity might reduce the level of intimacy and disable immediacy, which leads to negative sentiment in danmaku comments. It is suggested that the two new factors had more influence on users' social presence. Therefore, even though active users were anonymous, their social interaction was still more positive and engaging.

Nonetheless, we want to emphasize the limitations of this research, which uses Chinese online users' danmaku behavior. Users with varying cultural backgrounds exhibit different online behaviors [91]. What danmaku design implies to the development of social presence theory for online interaction needs further investigation.

5.3 Design Implications

Video has been used as a powerful medium for learning [64], and a recent survey study of Chinese online users suggested that danmaku could be leveraged to better facilitate user engagement in an online learning environment [97]. Our findings in terms of the improved user participation, collective emotions, language patterns, and complementary knowledge sharing further showed danmaku's potential in online video learning. System designers and developers can benefit from our work when addressing key issues of online videos.

First, caption providers can help address video accessibility issues [35] by posting captions using the danmaku feature. Our findings show that danmaku promoted the crowdsourcing of both closed and explanatory captions. Student plotters may help other students better understand the structure of the video lectures by making forecasting comments.

Even though there may be unavoidable negative comments in danmaku, active users' positive comments will help improve users' watching experiences by making the videos more fun to watch, which is one of the major perceived benefits of danmaku [49, 97]. Danmaku terms can be provided and gradually created in a danmaku dictionary, which will facilitate their communication with other users more effectively. Though danmaku features seem to draw users actively contributing positive comments, some videos still need to be monitored to avoid overwhelming negative comments.

The complementary knowledge sharing promoted by danmaku and forum suggests that we should keep the discussion forum feature of the current online video learning system when introducing the danmaku feature. On one hand, danmaku design can make online users feel socially and emotionally connected with others and users may be able to construct and confirm meaning quickly through sending short danmaku comments. On the other hand, online students can engage in deeper conversations and debates on discussion forums. Such collaborative and communicative discourse is necessary for pursuing knowledge in distance learning [31, 41].

5.4 Limitations and Future Work

We collected danmaku and forum comments from the most popular danmaku video website, Bilibili.com, in China. The findings need to be further evaluated using other danmaku websites. We only examined how danmaku and forum comments addressed explicit or tacit knowledge sharing. Due to the anonymous danmaku design and layout, users cannot comment back-and-forth, thus we were not able to construct conversations for danmaku comments. The anonymous feature did not allow us to identify individual users who commented both in danmaku and forum in the same

video either. In addition, we selected five videos for each genre, thus the data was not large enough to conclude if there were any significant differences among the varying genres. In future work, we plan to collect more danmaku data to address these questions. We will apply more comprehensive measurements to evaluate the informativeness of comments in danmaku and forum, e.g., classifying information intention and clustering themes [15].

In this article, we compared danmaku and forum comments, which were both asynchronously created, on a Chinese video website. Recently, social network websites (e.g., Facebook Live Video streaming) released danmaku-like features for video sharing. It is worth investigating if/how the cultural background of the users impact the use of danmaku features. For example, in the U.S., social TV [12, 85] and YouTube live broadcast [75, 77] are popular. A recent preliminary study showed that compared to adjacent strollable (design of YouTube live broadcast), danmaku's synchronous overlay would make users recall more comments of interest [98]. Comparing knowledge sharing in danmaku and synchronous live comments may yield interesting findings as well.

6 CONCLUSION

Using both quantitative and qualitative methods, we compared 38,399 danmaku comments and 16,414 forum comments posted in 2017 on 30 popular videos on Bilibili.com. More users were involved in danmaku communication and they posted danmaku comments more frequently than forum comments. Certain active users made unique interactions with online videos or their peer users by posting danmaku comments, e.g., caption providers created video captions voluntarily. Overall, danmaku contained more negative comments than forums; however, active users made more positive comments in danmaku instead of in forum comments. The danmaku comments were more positive when users had heated discussions, which was not found in forum comments. Memes were found in more danmaku comments and facilitated online collaboration through labeling users. One of the most important findings is that danmaku and forum comments enabled knowledge sharing in a complementary manner. More specifically, more explicit knowledge was shared in danmaku comments, and more tacit knowledge sharing was involved in forum comments. We discussed the potential of danmaku in the context of online learning using videos.

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