Danmaku vs. Forum Comments: Understanding User Participation and Knowledge Sharing in Online Videos

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ABSTRACT
Danmaku is a new video comment feature that is gaining popularity. Unlike typical forum comments that are displayed with user names below videos, danmaku comments are overlaid on the screen of videos without showing users' information. Prior work studied forum comments and danmaku separately, and little work compared how these two features were used. We collected 38,399 danmaku comments and 16,414 forum comments posted in 2017 on 30 popular videos on Bilibili.com. We examined the usage of these two features in terms of user participation, language used, and ways of sharing knowledge. We found that more users posted danmaku comments, and they also posted these more frequently than forum comments. Even though, in total, more negative language was used in danmaku comments than in forum comments, active users appeared to post more positive comments in danmaku. There was no such correlation in forum comments. It is interesting to find that danmaku and forum comments enabled knowledge sharing in a complementary manner, where danmaku comments involved more explicit knowledge sharing and forum comments exhibited more tacit knowledge sharing. We discuss design implications to promote social interactions for online video systems.

Author Keywords
Danmaku comments; forum comments; anonymous; synchronous; knowledge sharing; explicit knowledge; tacit knowledge.

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INTRODUCTION
Danmaku, a new video commentary feature, originated in Japan and now is very popular on Chinese video websites (e.g., Bilibili.com, AcFun.cn) [5], especially among young people. Unlike traditional video forums where comments are displayed below the video, danmaku comments fly from right to left on the video screen. Users can send danmaku comments anonymously and see other users' danmaku comments while they are watching the videos. Figure 1 illustrates the typical design of displaying the two types of comments using an example on Bilibili.com [5] (the most popular danmaku video website in China).

Compared to the forum design, which has been widely applied to the majority of video websites across different nations (e.g., YouTube), danmaku was adopted by video websites mainly in Asia. There has been increasing interest in the CSCW and CHI communities over the new social phenomena created by danmaku [45, 53, 28]. However, these two features (forum vs. danmaku) have been studied separately. For example, scholars found that users posted forum comments for varying purposes, e.g., sharing ideas, networking, and answering questions [32], as well as debating [46]. Regarding danmaku, Ma and Cao discovered that users applied different strategies to communicate effectively using danmaku, e.g., using different colors to distinguish user groups [28]. Yao et al. also conducted a survey study to understand the perceived benefits and drawbacks of danmaku [53]; e.g., users perceived that danmaku made the video more fun but also contained a large number of critiques and insulting language [53]. Little research compared the usage of the two comment features.

To address this gap, we collected 38,399 danmaku comments and 16,414 forum comments posted in 2017 on 30 recent and popular videos on Bilibili.com. We compared these two types of comments in terms of user participation, language patterns

Figure 1. User interface of displaying danmaku and forum comments on Bilibili.com. For example, Bilibili.com offers the following three danmaku modes: 1) Rolling danmaku, the default mode, where users' danmaku comments fly from right to left on the screen; 2) Top danmaku centers the comments on the top of the screen; 3) Bottom danmaku centers danmaku comments at the bottom of the video window. Users can select different display modes, colors and fonts for their danmaku comments.

and ways of knowledge sharing. Our work makes the following major contributions by providing empirical evidence of new knowledge: (1) the new danmaku feature promoted user participation compared to traditional comment features using forums; (2) even though there was more negative language in danmaku than in forum comments overall, active users posted more positive danmaku instead of forum comments; and (3) the ways of sharing knowledge in danmaku and forum comments are complementary, where more explicit knowledge is shared in danmaku. Our findings shed light on future design possibilities for online video websites.

RELATED WORK

Compared to forum comments, danmaku has two major perceived features: (1) building a "Pseudo-Synchronized" communication experience [41], 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 [28] and (2) posting anonymously. In this section, we review relevant literature on how synchronous and anonymous interactions impact user participation in online communities.

In addition, both studies on traditional forum [32, 46] and danmaku [28, 8] found that users posted comments for different purposes, including to answer questions [28, 32], to share opinions [53, 46], etc. Thus, we also review relevant literature on knowledge sharing in online communities, and develop our hypotheses.

Synchronization and Anonymity in Online Communication

Providing synchronous communication media is predicted to improve user participation [40]. For example, in an online business writing classroom, students generated a significantly larger amount of discussions when interacting with each other via the synchronous conference option [31]. It was also found that users wrote significantly more sentences in synchronous online discussions than in asynchronous discussions [18]. 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 [54].

Anonymity is also found to have a positive impact on user participation [23, 17, 14]. 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 [23]. 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 [17]. Through a scenario-based experimental study, researchers found that anonymous groups participated significantly more in chatting than identified groups [14].

Given that anonymous danmaku creates pseudo-synchronous experiences, and the above literature on user participation, 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 [34]. This loss of accountability results in an increased level of toxic disinhibition, consequently promoting impulsive, aggressive, and abusive behaviors [10]. 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 [49]. 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 [36]. Kilner and Hoadley observed that the prohibition of anonymous posts on a military professional education site almost completely eliminated negative comments [23]. Based on the literature, we developed our second hypothesis as below.

H2: Danmaku comments are more negative than forum comments.

Knowledge Sharing in Online Communities and Social Networks

Prior studies found that users posted danmaku comments for crowdsourcing captions [30], explaining terminologies [26] and debating [26]. Forums, e.g., on YouTube, can be a public space for answering questions [32], engaging in debates and exchanging opinions about various topics [46]. These two types of commenting provide different ways of knowl-

edge sharing on video websites, however, little research investigates if/how users shared knowledge differently through these two types of comments on video websites.

Scholars have been using Brown's definitions of explicit knowledge and tacit knowledge to differentiate ways of knowledge sharing [6], e.g., in healthcare systems [42, 1], e-government [37], and social media [39].

Explicit knowledge is referred to as "know-what" knowledge and expressed in words, numbers or symbols, and stored in databases, memos, notes, or documents, etc. This type of knowledge is formalized and codified, thus it is easier to identify, store, retrieve and communicate [52]. Tacit knowledge is referred to as "know-how" knowledge. It can be defined as experiences, beliefs, values, intuitive feeling, mental model, skills and observation in people's minds [11, 39]. The key to acquiring tacit knowledge is through sharing experience or people's thought processes [24].

For example, studies found that the social web paradigm was helpful for tacit knowledge sharing through interactive and collaborative technologies, such as social networking and online discussion forums [1]. Happer et al. found that on social Q&A sites, users asked informational questions and conversational questions which aimed to simulate discussions for sharing expression and opinions [15], promoting tacit knowledge sharing. 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 [39].

In this paper, we collected archived danmaku and forum comments to test the following hypothesis.

H3: Both danmaku and forum comments exhibit the same pattern of knowledge sharing where more tacit knowledge is shared than explicit knowledge.

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.

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 data sets in the same time frame. The data collection was conducted between March and May in 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.

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

Table 1. Basic information regarding the videos and collected comments according to the six genres.

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 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.

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 [6] 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' own experiences, e.g., "The cell phone signal of China Telecom works well in the dorms of my university", and "The commentor [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, 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 ($0.61 \sim 0.80$) [51]. Finally, a third coder resolved the disagreement with the first two coders together using the "majority rule" approach.

FINDINGS

In this section, we present our findings in order of answering the proposed hypotheses.

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.

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**)

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 that in forum ($N = 30$, $Mean = 343$, $SD = 366$, $V = 392$, $p < 0.01$).

We also compared user's 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 [25] 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 ($N = 10,148$, $Mean = 1.45$, $SD = 0.42$, $t = 2.72$, $df = 44$, $p < 0.01$).

Unique Active Users in Danmaku

There were not only more comments but also more users active in danmaku than forum. To address why there were more active users in danmaku, we reviewed the top 20 active users in both danmaku and forum respectively to examine how they made comments. Interestingly, these active users in danmaku comments 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 call 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]", etc. 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.

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 in 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's 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 also 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" [22]. 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.

Language Style

Sentiment Analysis

To conduct sentiment analysis, we used a tool called SnowNLP, which has been applied for sentiment analysis of microblog comments in Chinese [38]. 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. As a result, danmaku comments ($Mean = 0.580$, $SD = 0.072$, $25^{th} percentile = 0.402$, $75^{th} percentile = 0.825$) were more negative than forum comments ($Mean = 0.615$, $SD = 0.115$, $25^{th} percentile = 0.329$, $75^{th} percentile = 0.956$). Due to unequal sample sizes and unequal variances of sentiment scores for the two kinds of comments, we conducted Games-Howell tests for post-hoc pair-wise comparisons. The results also showed that danmaku comments were significantly more negative than forum comments ($t = 11.90$, $df = 26$, $p < 0.001$). (**H2 supported**)

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 ($t = 1.52$, $df = 16,412$, $p = 0.130$).

Terms and Language Patterns

The use of danmaku terms forms a unique danmaku culture [29]. Danmaku terms originate from various sources, e.g., several popular videos, slang terms online, and other languages or cultures (Japanese, Korean) [13]. These terms are used gradually by more and more users in danmaku comments. To investigate how danmaku terms were used in danmaku comments and forum comments, we searched danmaku slang terms on two popular encyclopedia websites, i.e., Baidu Baike [4] and Moegirlpedia [33]. Baidu Baike is a mainstream online encyclopedia which provides an encyclopedia term list, "Danmaku Terms", containing up to 123 danmaku terms. Moegirlpedia is another crowdsourced encyclopedia which creates up-to-date popular "Danmaku" terms.

We combined the danmaku terms from the two sources into a comprehensive collection of 1,134 slang terms in total. To pre-process the comment data, we applied a popular Chinese tokenizer, Jieba, which allows to upload a self-developed library. When analyzing the data, we took the slang term collection as the self-developed library that successfully avoided Jieba tokenizer from separating slang terms into separate tokens. Then we counted the frequency of terms used in danmaku comments and forum comments respectively.

There were 364 slang terms used in the 38,399 danmaku comments, and each term was used 26.88 times on average ($SD = 128.74$). Similarly, there were 337 slang terms used in the 16,414 forum comments, and each term occurred 18.02 times on average ($SD = 41.22$). Slang terms were used more frequently in danmaku comments than in forum comments.

Most danmaku terms were used to express emotions or opinions related to the video content. For example, users used many special characters which were easier to type, e.g., "233333" (laugh out loud), "hhhhhh" (onomatopoeic words to imitate laugh sounds), and "666666" (compliment to the roles), to express stronger emotions towards the video content compared with traditional comment language. It is found that danmaku users entertain each other to meet their psychological need and they aren't concerned with whether these emotions or opinions can create actual utility (e.g., persuading others) [19].

We also found that several terms were used to interact with other users. These danmaku terms 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" (a term to call for a large number of danmaku comments with different colors to cover the video screen) or "Subtitle group" (call for subtitle 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" (agree with previous comments). These danmaku terms were used by the users to construct a norm in the danmaku community.

We further 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 ($Mean = 45.23$, $SD = 4,920$, $t = 65.6$, $df = 17$, $p < 0.001$).

Knowledge Sharing

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

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%

Table 2. The distribution of explicit and tacit knowledge in different video genres.

in forum comments ($X^2 = 228.33$, $df = 1$, $p < 0.001$). (**H3 not supported**)

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", "Sleeping soft tissue fluid comes from the kidneys", "Electromagnetic waves could be transmitted in vacuum"; (2) Social Science, e.g., "The race does not determine the culture, but the culture determines the attributes of human beings", "England is a united kingdom, it indeed consists of four countries, not four districts", and "The nature of comedies is satire"; (3) Technology, e.g., "[The pictures] whose visual are round were taken by wide-angle lens", "This is not a dynamic wallpaper, it's called Live Photos", 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"; and (4) Other Information, e.g., "The lady in blue cheongsam is an actress in the movie Mr. Donkey", "The back ground music is River Flows in You", and "[The boxer] with blue gloves is from China" (one user asked which boxer was from China).

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", "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", and "Respect women but not support the materialistic feminism, women should be protected"; (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)", "Personally, I prefer the home button on the Samsung phone", and "[This was] made by Keynote. Those pages were easy to make by Magic Move"; and (3) Community-based, which means specific knowledge (rules, norm) in danmaku context, e.g., "Please keep in mind that it is extremely disrespectful to mention other uploaders" (Uploader is who uploaded videos), and "Folks, please actively report the insulting comments".

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 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 which 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 which is also about feminism)". Interestingly, users also shared where the video title *"I feel really sorry for it"* came from and came up 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 was brought 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), female in politics, female discrimination in workplace, and equality of men and women in China, etc. Users shared more arguments (e.g., their own experiences, or laws) to demonstrate their opinions, and the arguments were longer than those in danmaku.

As another example, an educational video, entitled *"China Eye Plans to Shock the World, Hawking Has Repeatedly Warned to Stop, Jealousy?"*, was about Chinese FAST (the biggest spherical radio telescope) program. In danmaku comments, users mainly discussed what FAST was used for, and its scientific, ethic and political issues in the exploration of outer space. In addition, users also shared their opinions about extra-terrestrial intelligence. It's worth mentioning that the users also shared a 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 more about why China developed FAST program and Hawking's theory.

DISCUSSION

We developed and tested three hypotheses to compare danmaku and forum comments in terms of user participation (**H1**), sentiment of language used (**H2**), and knowledge shar-

ing (**H3**). In this section, we reflect on our findings, and discuss design implications and limitations.

Unique User Groups and Interaction using Danmaku

Anonymity encourages users' early and continued participation [3] and the sense of security provided by anonymity can encourage students to share their thoughts more freely[50]. Therefore, it is not surprising that there were more anonymous danmaku comments than user-identified forum comments (**H1**).

However, 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) [12, 27, 47] 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 [35]. Comments of community norm regulators can alert users who violated the "rules". For example, we found that users tried to build the norms regarding where to position danmaku by posting danmaku comments, e.g., "Could you not post the danmaku at the bottom? it bothers me from reading the captions :)", or "The danmakus at the bottom are really annoying".

Active Users Posting Positive Comments in Danmaku

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 [16], however, our findings can not be well explained by existing literature which typically claimed anonymity resulted in more negative comments [49, 36, 23].

We also observed that active users in danmaku tended to express their emotion. For example, to express emotion, active users sent numeric characters such as "2333" and alphabetical characters such as "hhhhhh" to express their happiness. They also seemed post the same comments repeatedly or type longer comments to express stronger emotion, e.g., "Ah ha 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". We also found that the top one 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", "ò___ó" to mimic a smiling face. In fact, once a commenting style was created, other users tended to quickly learn the "languages". Given that the numeric character comments received neutral sentiment scores and the happy comments received positive sentiment scores, their frequent emotion sharing comments for fun [53] may help explain the language patterns we observed.

The above language patterns were very similar to that in online chat [2], where abbreviations, taboo words, short and simple sentences are frequently used. The unique features of danmaku comments are that users can also leverage colors and posting modes to support their expressions of different comments. For example, when they want to alert others, they post danmaku comments in bright colors. Video caption providers typically post their danmaku comments at the bottom of the screen.

Complementary Knowledge Sharing

We applied Brown's definitions of explicit knowledge and tacit knowledge to differentiate ways of knowledge sharing [6] in online video websites. The findings rejected our hypothesis regarding knowledge sharing on danmaku (**H3**).

Our finding–the traditional forum comments involved more tacit knowledge sharing–was aligned with the prior literature [15, 39]. 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 [21, 18]. If we examine the data more closely, according to Table 2, more explicit knowledge sharing seemed occur in video genres such as drama and sports, and much less explicit knowledge were shared in games and anime videos. In future work, we plan to test if users shared knowledge differently when commenting on different video genres.

Design Implications

A recent online survey study of 213 Chinese online users suggested that danmaku could be leveraged to better facilitate user engagement and interaction in an online learning environment [53]. Our findings in terms of the improved user participation, positive sentiment of comments, and complementary knowledge sharing further showed danmaku's potential in online video learning.

First, caption providers can help address video accessibility issues [20] by posting captions using the danmaku feature. Student plotters may help other students better understand the

structure of the video lectures by making forecasting comments.

Even though there may be negative comments in danmaku unavoidably, 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 [53, 28]. Danmaku terms can be provided and gradually created in a danmaku dictionary, which will facilitate their communication with other users more effectively.

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.

Limitations and Future Work

We collected danmaku and forum comments from the most popular danmaku video website, Bilibili.com. 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. In the future, we will apply more comprehensive measurements to evaluate the informativeness of comments in danmaku and forum, e.g., measuring informativeness priority, classifying information intention, and clustering themes [9]. Due to the anonymous danmaku design and layout, users cannot reply to individual users, thus we were not able to construct conversations among the danmaku users. We plan to conduct qualitative studies to gain a better understanding of how users interact with each other through danmaku comments.

In this paper, we compared danmaku and forum comments, which were both asynchronously created, in 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 genres of the videos on social media and the cultural background of the users impact the use of danmaku features. For example, in the U.S., social TV [7, 48] and YouTube live broadcast [43, 44] 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 [54]. Comparing knowledge sharing in danmaku and synchronous live comments may yield interesting findings as well.

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. Slang terms and shorter comments were more found in danmaku comments. 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 great potential of danmaku in the context of online learning using videos.

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