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What Motives Users to Participate in Danmu on Live Streaming Platforms? The Impact of Technical Environment and Effectance

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Abstract: Danmu function as an augmented comment feature has been adopted by almost all live streaming platforms to foster interaction between viewers and the streamer in China. However, few studies have been conducted to understand the determinants of users' Danmu sending behavior on live streaming platforms. This study examines this phenomenon from the lens of effectance theory and the S-O-R framework. We propose that two effectances – Danmu effectance and live streaming effectance – play an essential role in active Danmu participation. In addition, we explore the effects of time-enhanced (synchronicity) and space-enhanced technical characteristic (visibility) of Danmu on live streaming platforms on two effectances. Data analysis of 877 participations from Douyu platform in mainland China indicates that active Danmu participation is positively associated with Danmu effectance and live streaming effectance which are influenced by both time-enhanced technical feature (synchronicity) and space-enhanced technical feature (visibility). In addition, the study finds that demographic characteristics, namely education and income, also affect active Danmu participation.

Keywords: Danmu, live streaming, synchronicity, visibility, effectance, active Danmu participation

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1 Introduction

Live streaming has become a widespread phenomenon across the world. The streamer can broadcast a variety of content on live streaming platforms ranging from gaming to dancing and singing without any geographic barriers. Viewers can directly chat with the streamer or other viewers by sending real-time comments on the live streaming, aka Danmu. This potential of real-time interaction and influencing the live stream has led to widespread use of live streaming services. Data from a study conducted by Interactive Advertising Bureau (IAB) show that in July 2018, more than 66.7% of consumers globally had the experience of watching live streaming (Laura Goldberg, 2018). China Internet Information Center (CNNIC) estimates that there are 425 million live streaming users by June 2018, representing 53.0% of all internet users (CNNIC, 2018). According to a 2018 report of Research and Markets, global live streaming revenue is projected to rise from USD 30.29 billion in 2016 to USD 124.57 billion by 2025 (Research and Markets, 2018). The revenue from live streaming in China reached RMB 30.45 billion in 2017 (Xinhua, 2018) and is anticipated to reach around RMB 112 billion by 2020 (Statista, 2018).

Danmu as an augmented comment feature has been adopted by almost all live streaming platforms in China (such as Douyu, Huya, and Inke). Users can post Danmu comments while watching live streaming and these comments are displayed synchronously on the live streaming, scrolling from right to left until they disappear from the screen (see Appendix A: Figure 1). Danmu ("danmaku" in Japanese) is originated from a video sharing site named Niconico in 2006, which is the tenth most visited website in Japan according to Alexa (http://www.alexa.com). Unlike conventional online video platforms such as YouTube or YOUKU, where user-generated comments are provided below the video, Danmu video websites enable comments to be displayed on the video and is synchronized with the specific playback time

of the video. Danmu comments sent by viewers move from right to left on the screen and create an illusion that viewers' posting behavior is live. Danmu comments on live streaming websites are synchronous as against those on Danmu video websites (Johnson, 2013), That means users can see real-time Danmu comments sent by other viewers on the screen and send Danmu comments without delay while watching live streaming. Thus, the Danmu function on live streaming platforms offers users an opportunity to directly interact with the streamer and other viewers.

Though Danmu function has a great impact on the live streaming systems, it is still under-explored by researchers. Scholars have mainly focused on Danmu phenomenon on online video platforms (Fan et al., 2018, 2017; He et al., 2017; Liu et al., 2016; Shen et al., 2014), but paid less attention to that on live streaming platforms. Prior studies have found the synchronous communication can boost user participation in online community (Hrastinski, 2008; Robert & Dennis, 2005). Considering the pseudo-synchronicity of Danmu on online video websites (Fan et al., 2017), the underlying psychological mechanism behind Danmu sending behavior on live streaming may be different. Moreover, studies on Danmu phenomenon have explored the motivation behind watching behavior on Danmu video websites (Bründl et al., 2017; Chen et al., 2017; Fan et al., 2017) and paid less attention to posting behavior (Zhang & Sun, 2018). Compared with the watching behavior, posting behavior requires more attention, time, energy, and knowledge (Butler, 2001). The underlying theoretical mechanism between watching behavior and posting behavior should be different. And users posted more comments on Danmu websites than on traditional online video websites (He et al., 2017; Lin et al., 2018; Wu et al., 2018). The Danmu function can also be beneficial for development of platforms such as improved user participation (Lin et al., 2018) and video popularity (He et al., 2017).

Studies have identified a number of reasons behind individuals posting online comments in traditional asynchronous online environment, including economic incentives (Burtch et al., 2017; Sun et al., 2017), social norms (Askalidis et al., 2017; Burtch et al., 2017), altruism (Hennig-Thurau et al., 2004; Mathwick & Mosteller, 2017), and social interaction (de Vries et al., 2017; Sun et al., 2017). However, on the live streaming platforms, the user-generated comments are displayed as streams of moving subtitles overlaid on the video screen, whereby users can simultaneously communicate with other viewers and the streamer by sending Danmu comments. Less work has been done to investigate the effect of technical features of Danmu on Danmu sending behavior on live streaming platforms, where viewer–streamer and viewer–viewer interactions occur. Moreover, the underlying psychological mechanism behind active Danmu participation in the synchronous online context is also unknown.

Considering this gap, the aim of this research is to investigate the motivation behind user participation on live streaming platforms using Danmu function. We specifically examine the following: (i) *What are the primary technical characteristics of Danmu on live streaming platforms?* and (ii) *What drives users to send Danmu comments while watching live streaming?*

We propose two primary technical characteristics of Danmu on live streaming platforms, namely, synchronicity and visibility. These two concepts reflect time-enhanced technical characteristic and space-enhanced technical characteristic of Danmu on live streaming platforms. *Synchronicity* means that Danmu comments will display immediately on the video screen when posted by the user on live streaming platforms. *Visibility* implies that user's Danmu comments overlaid on the video screen will be noticed by co-viewers and the streamer on the live streaming platforms (see Appendix A: Figure 1). This paper attempts to enhance the understanding behind active Danmu participation on live streaming platforms from the effectance theory perspective. White (1959) first posited the concept of "effectance" according to which humans have an urge to have an impact on their environment and they will have a positive feeling when they can create a perceptible change in their surroundings. The latent urge to experience this feeling is the drive behind their behavior. Based on the effectance theory, we posit two effectances – Danmu effectance and live streaming effectance. Danmu effectance implies that an individual user perceives change in the content of Danmu through his or her comments. Live streaming effectance implies that an individual user perceives change in the content of live streaming through his or her comments. These two effectances motivate users to send Danmu comments to interact with co-viewers or the streamer on live streaming platforms.

This study makes several theoretical contributions to the literature. First, we contribute to literature on Danmu posting behavior by providing an enlightened understanding of psychological mechanism behind users' active Danmu participation using effectance theory and the S-O-R framework. Second, we extend the literature on Danmu by examining the role of technical characteristics of Danmu on effectances. Third, we contribute to the literature on effectance theory by applying it to the information systems domain of live streaming and investigating the effects between different types of effectances.

In this paper, we first review the theoretical foundation and relevant literature. We then describe the research model and develop the hypotheses, followed by research methodology and data collection. We then present data analysis and results. We finally conclude the paper by discussing the theoretical and practical implications and limitations and suggest avenues for future research.

2 Literature Review and Theoretical Background

2.1 S-O-R Framework

Originating from the field of environmental psychology, the S-O-R framework describes that the external environment, acting as stimuli (S), affects users' internal organisms (O), and subsequently, their behavioral responses (R) (Mehrabian & Russell, 1974). In the online environment, stimuli represents the characteristics of website design that users interact with (Eroglu et al., 2003). The organisms reflect users' emotional and cognitive states, including their perception, experiences, and evaluation (Jiang et al., 2010). The responses refer to user behaviors, such as purchase behavior (Zhang et al., 2014) and posting behavior (Zhang & Sun, 2018).

The reason that S-O-R framework is suitable for this research is twofold. First, some scholars have applied the S-O-R framework in Danmu video websites context (Fan et al., 2017; Fang et al., 2018; Zhang & Sun, 2018). For example, Fan (2017) adopted the S-O-R framework to examine the effects of Danmu characteristics in online video website on users' co-experience and subsequent content consumption activities. Using the S-O-R framework, Liu (2016) explored the impacts of media capabilities of Danmu system on perceived interactivity and intention to share and use the Danmu system. These examples have supported the applicability of the S-O-R framework to explain users' internal reactions and behavioral responses to external environment. Second, considering the role of technical features of Danmu and user's perception in influencing subsequent users' behaviors in Danmu video websites, the S-O-R framework is concise and suitable to explore the impacts of technical characteristics of Danmu on live streaming platforms (stimuli), on effectance (organisms), and, in turn, their active Danmu participation (responses).

2.2 Technical Characteristics of Danmu as Stimuli (S)

No agreed upon definition of Danmu exists among scholars. Most scholars, however, agree that Danmu is characterized by user-generated comments displayed as streams of subtitles moving from right to left on the video screen and synchronized with the specific playback time of the video (Fan et al., 2017; Fang et al., 2018; He et al., 2017; Johnson, 2013; Liu et al., 2016). Danmu can be seen as augmented comment feature for two reasons (Fan et al., 2017; Liu et al., 2017). First, the Danmu comments are overlaid on the video screen rather than in a separate comments area. Second, the Danmu comments are organized based on the video timeline. A few scholars have focused upon the technical features of Danmu. Fan (2017), for example, conceptualized three technical features of Danmu on online video websites from the time, space, and support perspectives. Pseudo-synchronicity captures the time dimension and reflects that the time of Danmu comments sent by users is actually different (Johnson, 2013). Pseudo-proximity captures the space dimension and has been further classified into spatial proximity and temporal proximity (Fan et al. 2018). Spatial proximity refers to the physical closeness between the Danmu comment area and the focal area of the video section, whereas temporal proximity refers to the temporal closeness between the Danmu and the video (Fan et al., 2018). Comment-content congruency reflects the support dimension and refers to the consistency between the content of the Danmu comments and the video.

The distinguishing characteristic of Danmu comments in live streaming is that all activities are synchronous, which means there is no difference in time between users' posting and reacting to the comments. Users can send real-time Danmu comments when watching live streaming and these comments are overlaid on the video screen so as to be visible to all the co-viewers and the streamer. The user can passively watch the live streaming or choose to interact actively with the streamer or other viewers by sending Danmu comments. Meanwhile, the streamer may respond to Danmu comments displayed on the video screen. Such synchronicity in communication can boost user participation in the online community (Robert & Dennis, 2005). Previous study also showed that interaction between users is more intense in synchronous online discussions than in asynchronous online discussions (Hrastinski, 2008). Considering the pseudo-synchronicity of Danmu in online video websites, the underlying theoretical mechanism behind Danmu sending behavior between online video setting and live streaming context

may be different. However, research has not examined the technical characteristics of Danmu in live streaming. Moreover, prior studies on live streaming have also ignored the Danmu sending behavior. Therefore, it is essential to consider the technical characteristics of Danmu to better understand the psychological mechanism behind active Danmu participation. Based on the above discussion, we propose two main technical characteristics of Danmu on live streaming platforms: synchronicity and visibility.

Synchronicity refers to the degree to which individual user can receive multiple Danmu comments and give real-time feedback without delay (Dennis et al., 2008). This construct captures the time-enhanced technical characteristic on live streaming platforms, and it means activities between viewers and streamer or other viewers are real time. Users can send real-time Danmu comments while watching live streaming and all viewers can see the Danmu comments on the video screen simultaneously and both live streamer and viewers can also respond to these Danmu comments in real time.

Visibility refers to the degree to which a user's Danmu comments overlaid on the video are noticed by co-viewers and the streamer (Leonardi, 2014). This construct captures the space-enhanced technical characteristic on live streaming platforms, which means user-generated comments overlaid on the video screen can be seen by co-viewers and the streamer. Unlike the traditional comments display separated from the video, less effort is required to access the Danmu comments because they are organized as the live streaming timeline on the video screen moving from right to left (Berkelaar & Harrison, 2017). Thus, individuals may be sure that their Danmu comments are observed by other viewers and the streamer.

2.3 Effectance as Organisms (O)

White (1959) first proposed effectance theory. This theory is different from traditional explanations of human behavior based on drive concept and anxiety reduction. Effectance theory holds that humans have an inherent psychological urge to make things happen and to impose an impact on the environment, which is effectance motivation (White, 1959). Humans experience a positive feeling of efficacy when they can create a perceptible change in their surroundings, and the underlying desire to experience this feeling is the drive behind their behavior. The behaviors motivated by the effectance motivation are "merely something that is interesting and fun to do" (White, 1959). Based on this assumption, Harter (1978) further added that when one is successful in creating the intended effect, one can experience a great feeling of efficiency than when one creates an effect that is different from what he/she intended. So, the effectance motive is to develop competence in interacting with the environment (Lamont, 1983). Kusyszyn (1990) suggested another existential interpretational of effectance motivation. By interacting effectively with the environment and receiving feedback in the form of perceived change, we are able to affirm that we are alive and have worth (Kusyszyn, 1990). Kusyszyn (1990) broke down three different areas of effectance: a need to have an effect on other people (effect on people), a need to have an effect on inanimate objects (effect on objects), and a need to competently affect ourselves (effect on self).

Effectance theory has been adopted to explain the phenomenon in playing computer games (Klimmt & Hartmann, 2006; Klimmt et al., 2007), interactive storytelling (Klimmt et al. 2012), and social live streaming services (Bründl et al., 2017). The concept "effectance" is used to explain why players choose to play computer games (Klimmt & Hartmann, 2006) and is strongly linked with the enjoyment behind playing computer games (Klimmt et al., 2007). In the computer games environment, the games immediately respond to every single input by players, and the perception of having an effect within the game environment is important. This allows players to perceive clearly the effect they impose on the environment. The resulting perceived change in surroundings is very pleasurable and rewarding, and this feeling drives players to continue playing games. Similar to computer games, the synchronous communication in live streaming offers users the opportunity to affect the content of Danmu or live streaming by their Danmu comments. According, users' action with successful influence on the content of Danmu or live streaming will lead to a perception of effectance. Therefore, the effectance theory can be applied to study the Danmu phenomenon on live streaming platforms. Bründl (2017) studied the relationship between effectance and enjoyment of watching and chatting in social live streaming services, but this context is different from the live streaming platforms in China. The effectance theory in the context of Danmu phenomenon on live streaming platforms is still under-explored in current studies. We still do not know the effect of effectance on Danmu sending behavior and how the technical features of Danmu play a role in effectance. And the research has also not examined the effectance from different dimensions.

Based on the effect on the objects (Kusyszyn, 1990), we attempt to break down the effectance into two dimensions from the effect on content of Danmu and live streaming, namely Danmu effectance and live streaming

effectance. *Danmu effectance is defined as perceived influence user imposes on the content of the Danmu through his or her Danmu comments*. That means other viewers are influenced by user's Danmu comments and react to the user. *Live streaming effectance is defined as the perceived influence user imposes on the content of the live streaming through his or her Danmu comments*. That means the streamer observes user's Danmu comments on the video and reacts to the user.

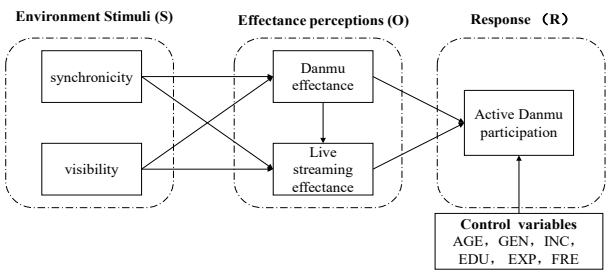

Figure 1. The research model

2.4 Active Danmu Participation as Response (R)

Active participation by members is of critical importance for the success of social media (Algesheimer et al., 2005; Choi, 2013; Lee et al., 2015). Social media is successful, when it attracts active participation from a large percentage of members (Rau et al., 2008). Active comment participation in social media is characterized by posting comments (Kuem et al., 2017), joining in a discussion (Gharib et al., 2017) and replying to posted comments (Gharib et al., 2017). Similar to active commenting in social media, user can post Danmu comments, join in discussion through Danmu comments, and reply to other user or the streamer by sending Danmu comments when watching live streaming. Therefore, we define active Danmu participation *as the degree to which user sends Danmu comments, replies to others' posted Danmu comments, and joins in group discussion or communication through Danmu comments* (Gharib et al., 2017; Kuem et al., 2017).

Users by watching Danmu seek information, entertain themselves, and develop a sense of belonging (Chen et al., 2015, 2017), whereas by posting comments, they also contribute to information in the site. Contributing content requires more attention, time, energy, and knowledge (Butler, 2001). Since the sending behavior is more active than watching behavior (Shang et al., 2006), the underlying psychological mechanism behind two behaviors should be different. But most studies on Danmu have focused upon watching behavior (Chen et al., 2015, 2017; Fan et al., 2017; Peng et al., 2016; Zhang & Sun, 2018) and paid less attention to the Danmu sending behavior (Zhang & Sun, 2018).

Previous studies note that people post Danmu comments more frequently than posting comments on online video platforms (He et al., 2017; Lin et al., 2018; Wu et al., 2018). This implies that the underlying motivation in sending Danmu is different from posting traditional comments. Previous studies have investigated the antecedents of review posting behavior in traditional online websites including economic incentives (Burtch et al., 2017; Kuem et al., 2017), social norms (Askalidis et al., 2017), altruism (Hennig-Thurau et al., 2004), and social interaction (de Vries et al., 2017; Sun et al., 2017), whereas these studies did not consider the effects of technical features of websites on the motivation of posting behavior.

3 Research Model and Hypotheses

Figure 2 summarizes the research model. We examine the drivers of active Danmu participation in live streaming using the effectance theory and the S-O-R framework. Now, we discuss the theoretical grounding of the constructs and our research model.

3.1 Effects of Technical Characteristics on Effectance

As discussed earlier, synchronicity and visibility are two technical characteristics of Danmu on live streaming platforms. Klimmt (2012) noted that a system that allows smooth interaction between the user and the game without any time lag evokes the experience of effectance. In the context of computer games, the speed of ball reacted to inputs by players will affect players' perceived effectance (Klimmt et al., 2007). Prior studies also reported that the synchronous features of live streaming can help viewers shape the broadcasted content via chat comments (Tang et al., 2016). When individual user sends real-time Danmu comments on the live streaming platforms, other audiences can see the real-time Danmu comments overlaid on the video and may be influenced by the content of the Danmu comments. Meanwhile, the individual user can also obtain the synchronous feedback from co-viewers on the screen when other viewers reply to the Danmu comments. From the perspective of the content of live streaming, the streamer can immediately see the

scrolling Danmu comments sent by all the viewers and he/she may respond to a specific viewer through words, facial expression, and body language or by changing the content of live streaming. The individual user can notice the change of live stream content based on the real-time feedback to the streamer, thus making live streaming effective. Hence, we hypothesize the following:

H1a: Synchronicity is positively correlated with Danmu effectance.

H1b: Synchronicity is positively correlated with live streaming effectance.

Visibility means Danmu comments will be displayed on the top of the video screen moving from right to left, if the user do not modify the default Danmu setting on live streaming platforms (see Appendix A: Figure 1). In interactive media research, the probability of a ball being displayed on the screen as a result of inputs from users in a video game will influence a user's perceived effectance (Klimmt et al., 2007). Danmu is different from chat comments displayed at the right of the website on live streaming platforms (i.e., Twitch, Facebook Live). Danmu as a special function of live streaming platforms in China, the user-generated comments are organized as live streaming timeline on the video screen moving from right to left will make it easy for other viewers and the streamers to read (Berkelaar & Harrison, 2017). Previous studies have revealed that viewers are easily influenced by others' Danmu comments over time on online video platforms (He et al., 2017, 2016). So, the possibility of Danmu comments being read and responded to by all viewers increases and the user can obtain the feedback in real time. Meanwhile, the streamer will also be influenced by the Danmu comments displayed on the video screen by any individual user and respond to the user through words, facial expression, or body language in real time. Hence, we hypothesize the following:

H2a: Visibility is positively correlated with Danmu effectance.

H2b: Visibility is positively correlated with live streaming effectance.

The relationship between different effectances has not been examined in previous studies. Generally, the streamer will also be influenced by the Danmu comments displayed on the video screen by all users, and thus as a response to these comments, may change the content of live streaming. Hence, we hypothesize the following:

H3: Danmu effectance is positively correlated with live streaming effectance.

3.2 Effects of Effectance on Active Danmu Participation

According to the effectance theory, humans have an inherent psychological urge to make things happen and have an effect on the environment (White, 1959). Previous studies (Hamilton et al., 2014) on live streaming platforms noted that users enjoy the possibility of influencing the content of live streaming and the interaction between the streamer and user can also be rewarding for the user. Karhulahti (2016) further noted that users enjoy the feeling of their actions having an effect on live streaming in front of co-viewers. Effectance theory also posits that they will experience a positive feeling when they succeed in exerting influence on the surrounding, and the latent desire to experience this feeling is the motivation behind the behavior. Research in social live streaming services reveals that consumers try to affect the content of live streaming through chatting, which is enjoyable on its own (Bründl et al., 2017). Therefore, when an individual user perceives changes in the content of Danmu or the live streaming by his or her comments, he or she will have a positive feeling. And the urge to experience this feeling will drive him to participate in Danmu including sending Danmu comments, replying to other's posted Danmu comments, and joining in group discussion or communication through Danmu comments. Hence, we hypothesize the following:

H4: Danmu effectance is positively correlated with active Danmu participation.

H5: Live streaming effectance is positively correlated with active Danmu participation.

3.3 Control Variables

We also included several control variables that previous studies indicate affect active behavior in online community including gender (GEN), age (AGE), income (INC), education (EDU), length of experience in using live streaming (EXP) (Choi, 2013), and frequency of use (FRE) (Ma & Agarwal, 2007).

4 Research Methodology

4.1 Questionnaire Design

We adapt the existing validated measurement items from prior studies to suit the setting of this study. The items

of synchronicity were adapted from Liu (2003). Items for visibility were adapted from Fisher (1992) and Karahanna (1999). Items for Danmu effectance were adapted from Klimmt (2007). Items for live streaming effectance were adapted from Bründl (2017) and Klimmt (2007). Items for active Danmu participation were adapted from Gharib's (2017) and Kuem's (2017) measures of active participation in social media. We based all measures on 7-point Likert scales ranging from 1 (strongly disagree) to 7 (strongly agree). We also followed the back-translation method suggested by Brislin (1970) to convert English items into Chinese. In all, 11 IS researchers and Douyu users were invited to check the wording, legibility, and suitability of the scales and further refined the Chinese questionnaire according to their advice. Moreover, we conducted a pilot study to ensure reliability and validity of the scales. An online version of survey was designed and its hyperlink was posted on Wechat and QQ. The subjects who had experience of sending Danmu comments on Douyu website were invited to fill out the questionnaire. In all, 80 respondents were finally screened for the pilot study. The result of data analysis shows that Cronbach's alpha of all constructs were above 0.7, which implies a strong internal consistency of the constructs. We revised the questionnaire according to the feedback received from the subjects of the pilot study. The items are listed in Appendix B.

4.2 Data Collection

The subjects in this study are users of Douyu platform. Douyu (douyu.com) was launched in January 2014 and since then it has become one of the most famous live streaming platforms in mainland China. It provides a variety of live streaming content with a primary focus on games and also covers other entertainment activities such as talent show, music, and outdoor activities. According to the prospectus of Douyu, the Douyu platform had 159.2 million monthly active users and these users spent about 2.3 billion hours on Douyu platform in the first quarter of 2019 (DouYu International Holdings Limited, 2019).

We posted a survey hyperlink on Douyu website from March 18 to April 10, 2019. Respondents were required to recall the most recent live streaming channels they watched and answer the questionnaire based on their actual posting behavior. Respondents who filled out the survey successfully received small monetary rewards. To eliminate invalid data, we deleted questionnaires with same answer to all questions and no experience of sending Danmu comments and the answer time is under 5 minutes (minimal time required for completion based on

Table 1
Demographic Characteristics of the Respondents (N=877)

Category	Item	N	Percentage (%)
Gender	Male	520	59.3
	Female	357	40.7
Age (years)	<18	39	4.4
	19–24	345	39.3
	25–30	331	37.7
	31–35	131	14.9
	36–40	22	2.5
	>40	9	1.0
Education	High school or below	70	8.0
	Associate degree	149	17.0
	Bachelor degree	592	67.5
	Master's degree or higher	66	7.5
Occupation	Unemployed	6	0.7
	Student	249	28.4
	Corporate or government	518	59.1
	Freelances or self-employed	86	9.8
	Others	18	2.1
Monthly income (in yuan)	<3000	236	26.9
	3000–5000	179	20.4
	5000–10000	310	35.3
	10000–20000	137	15.6
	>20000	15	1.7
Length of Douyu platform usage	<3 months	30	3.4
	3–6 months	97	11.1
	6 months–1 year	207	23.6
	1–2 years	251	28.6
	>2 years	292	33.3
Average use frequency of the Douyu platform	Less than 1 time per week	295	33.6
	2–3 times per week	317	36.1
	4–5 times per week	191	21.8
	At least 1 time per day	74	8.4

Table 2
Common Method Bias Analysis

Construct	Indicator	Substantive factor loading (R_1)	R_1^2	Method factor loading (R_2)	R_2^2
Synchronicity (S)	S1	0.8026***	0.6442	0.0179	0.0003
	S2	0.7974***	0.6358	-0.0226	0.0005
	S3	0.7359***	0.5415	-0.0303	0.0009
	S4	0.7930***	0.6288	0.0299	0.0009
Visibility (V)	V1	0.8332***	0.6942	-0.0243	0.0006
	V2	0.8833***	0.7802	-0.0608*	0.0037
	V3	0.7698***	0.5926	-0.0448	0.0020
	V4	0.7207***	0.5194	0.1241***	0.0154
Danmu effectance (DE)	DE1	0.8367***	0.7001	-0.0430	0.0018
	DE2	0.8177***	0.6686	-0.0296	0.0009
	DE3	0.7615***	0.5799	0.0697*	0.0049
Live Streaming effectance (LSE)	LSE1	0.6679***	0.4461	0.0951*	0.0090
	LSE2	0.8459***	0.7155	-0.0011	0.0000
	LSE3	0.7466***	0.5574	0.0758*	0.0057
	LSE4	0.9143***	0.8359	-0.1741***	0.0303
Active Danmu Participation (ADP)	ADP1	0.8181***	0.6693	-0.0042	0.0000
	ADP2	0.8593***	0.7384	0.0165	0.0003
	ADP3	0.8028***	0.6445	-0.0028	0.0000
	ADP4	0.9324***	0.8694	-0.0906*	0.0082
	ADP5	0.5873***	0.3449	0.1478*	0.0218
	ADP6	0.8057***	0.6492	-0.0513	0.0026
Average		**0.7968**	**0.6408**	**-0.0001**	**0.0052**

Note: *p < 0.05, **p <0.01, ***p<0.001

the pilot test). Finally, 877 valid responses were left. We compared the means of all variables and demographics for early and late respondents and found there was no significant differences. Thus, the nonresponse bias did not exist in this study. The description of demographic characteristics of the respondents is shown in Table 1. Males accounted for 59.3% of the respondents. Most of the respondents were between 19 and 30 years (77%) and had received higher education in universities and or college (84.5%). Employees in corporate or government accounted for 59.1%. 61.9% of respondents reported that they have used Douyu platform for more than a year, and 66.3% of the respondents used Douyu platform at least two times in a week.

5 Data Analysis and Results

First, we tested the convergent and discriminant validity of the scale by conducting the principal component analysis. We used Kaiser–Meyer–Olkin (KMO) test and the result (0.924) showed that the data were suitable for factor analysis. All the items loaded on the expected factors and loadings on the expected factors exceeded 0.6, which implied good convergent and discriminant validity.

As data in this study were self-reported and from a single source, we conducted two tests to address the potential concern for common method basis (CMB). First, we followed Podsakoff and Organ (1986) to perform Harman's single factor test. The result indicated that five major factors accounting for 64.6% of total variance,

Table 3
Results of Confirmatory Factor Analysis

Factor	Item	Mean	SD	Factor Loading	Cronbach's a	CR	AVE
Synchronicity (S)	S1	5.74	1.142	0.816	0.788	0.862	0.611
	S2	5.86	1.116	0.758			
	S3	5.11	1.394	0.711			
	S4	5.46	1.233	0.836			
Visibility (V)	V1	5.55	1.291	0.803	0.814	0.877	0.641
	V2	5.22	1.446	0.841			
	V3	5.61	1.216	0.712			
	V4	5.12	1.445	0.840			
Danmu Effectance (DE)	DE1	5.05	1..310	0.797	0.728	0.846	0.647
	DE2	5.16	1.338	0.791			
	DE3	4.94	1.277	0.824			
Live Streaming Effectance (LSE)	LSE1	4.87	1.376	0.749	0.803	0.871	0.629
	LSE2	4.70	1.472	0.843			
	LSE3	4.85	1.377	0.814			
	LSE4	4.38	1.491	0.762			
Active Danmu Participation (ADP)	ADP1	5.34	1.431	0.811	0.890	0.916	0.647
	ADP2	5.28	1.374	0.871			
	ADP3	5.46	1.269	0.791			
	ADP4	5.42	1.327	0.845			
	ADP5	4.74	1.561	0.738			
	ADP6	5.38	1.339	0.764			

and the largest factor did not account for a majority of the variance (36.7%). Second, we tested our data for common method basis following Liang's (2007) method. A common method factor was included in the PLS model and it determines all indicators of the principal constructs. The result (see Table 2) showed that the ratio of average substantively explained variance of the indicator (0.6408) to average common method-based variance (0.0052) was about 124:1. In addition, most method factor loadings were not significant. Based on these tests, we concluded that common method bias was not a major concern in this study.

5.1 Measurement Model Test

We tested the measurement model using partial least squares (PLS) with SmartPLS version 2.0 (Ringle et al., 2005), which evaluates the measurement and structural models simultaneously (Gefen et al., 2000). The result is presented in Table 3. All Cronbach's alpha values and the composite reliabilities (CR) exceeded 0.70, suggesting a good reliability of the scale (Nunnally, 1978). Confirmatory factor analysis results revealed that all loadings of measurement scales were above 0.70. The average variance extracted (AVE) values of every construct exceeded 0.50, exhibiting a satisfactory convergent validity (Fornell & Larcker, 1981).

Discriminant validity was also tested. As shown in Table 4, the square root of the average variance extracted (AVE) of any latent variable (diagonal term) was greater than the correlations between this latent variable and other latent variables (off-diagonal terms) (Fornell & Larcker, 1981). All correlation coefficients between the latent variables are less than 0.6 except that the correlation between Danmu effectance and live streaming effectance

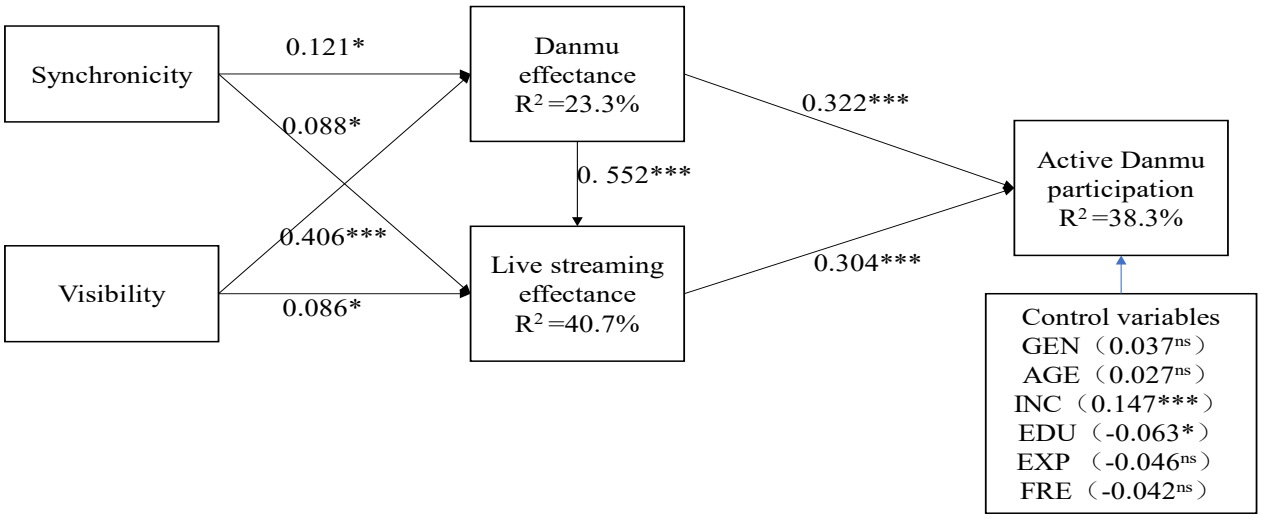

Figure 2. **Result of structural model test**
*p<0.05;**p<0.01;***p<0.001; ns: non-significant at the 0.05 level.

Table 4
Correlations and Discriminant Validity of Constructs

	S	V	DE	LSE	ADP
Synchronicity (S)	**0.782**				
Visibility (V)	0.549	**0.800**			
Danmu Effectance (DE)	0.344	0.472	**0.804**		
Live Streaming Effectance (LSE)	0.325	0.395	0.623	**0.793**	
Active Danmu Participation (ADP)	0.375	0.461	0.535	0.538	**0.804**

Notes: the square root of the average variance extracted (AVE) is displayed on the diagonal in bold font

did not meet the requirement (correlation coefficient = 0.623). However, result of a multicollinearity test revealed that this may not be a big problem because the variance inflation factors (VIFs) were less than 3 (Diamantopoulos & Siguaw, 2006). Moreover, the items loaded more strongly on its targeted construct than on any other constructs in the model (see Appendix C) (Gefen & Straub, 2005). Thus, we can conclude that our measurement instrument fulfills the requirements of discriminant validity.

5.2 Structural Model Test

A bootstrap analysis with 5000 resamples was performed to evaluate the structural model (Chin et al., 2003). Figure 2 shows the results of the structural model tests. Overall, the model explained 38.3% of the variance in users' active Danmu participation. Also, 23.3% and 40.7% of the variances were explained in Danmu effectance and live streaming effectance. Specifically, Danmu effectance was significantly related to synchronicity (β = 0.121, t = 2.489) and visibility (β = 0.406, t = 8.746), which supported H1a and H1b. Correspondingly, live streaming effectance was also found to be positively associated with synchronicity (β = 0.088, t = 2.489) and visibility (β = 0.086, t = 2.185), thus supporting H2a and H2b. Danmu effectance was significantly associated with live streaming effectance (β = 0.552, t = 18.462), thereby supporting H3. And active Danmu participation was positively associated with Danmu effectance (β = 0.322, t = 7.641) and live streaming effectance (β = 0.304, t = 7.665), thus supporting H4 and H5. In addition, we found that two control variables (education and income) had significant effect on active Danmu participation. Specifically, active Danmu participation was lower among more educated users than less educated users and was higher among higher income than lower income.

6 Discussion and Implications

6.1 Discussion of Findings

In this study, we examined the psychological mechanism behind users' Danmu sending behavior on live streaming platforms. Using a questionnaire-based survey of live streaming users on Douyu platform, we investigated the

relationship between technical features of Danmu on live streaming platforms, effectance and active Danmu participation through the lens of effectance theory and S-O-R framework. This study provides some interesting findings. First, drawing on the effectance theory, we found that users have two effectances, namely Danmu effectance and live streaming effectance. These two types of effectances have a significant effect on users' active Danmu participation. In addition, Danmu effectance is positively associated with live streaming effectance. This indicates that live streaming platforms provide an environment for users to influence the content of Danmu and live streaming, and they play an important role in affecting users' active Danmu participation. Second, regarding the time-enhanced technical characteristic of Danmu, synchronicity positively influenced Danmu effectance and live streaming effectance. For example, users can instantly experience the change in the content of live stream due to their Danmu comments. Third, regarding the space-enhanced technical characteristic of Danmu, visibility positively influenced Danmu effectance and live streaming effectance. For example, users or the streamer can be easily influenced by posting Danmu comments. Finally, we found active Danmu participation to be lower among those who were more educated and have lower income. One possibility is that more educated people might have less time and do not pay effort for sending Danmu comments. Similarly, higher-income people might have a greater possibility to influence the streamer and other users because their Danmu can be set with a bigger font, special location of the screen and distinct color.

Table 5
PLS Results

Category	DE	LSE	ADP
R^2	0.233	0.407	0.383
Independent Variables			
S	0.121* (2.489)	0.088* (2.489)	
V	0.406*** (8.746)	0.086* (2.185)	
DE		0.552*** (18.462)	0.322*** (7.641)
LSE			0.304*** (7.665)
Control variables			
GEN			0.037 (1.344)
AGE			0.027 (0.822)
INC			0.147*** (3.967)
DEU			-0.063* (1.995)
EXP			-0.046 (1.551)
FRE			-0.042 (1.260)

*p<0.05;**p<0.01;***p<0.001
Notes: S=synchronicity, V=visibility, DE=Danmu effectance, LSE=Live streaming effectance, ADP=Active Danmu participation, GEN=gender, AGE=age, INC=income, EDU=education, EXP=experience, FRE=frequency.

6.2 Theoretical Implications

With this study, we make several theoretical contributions to the literature. First, instead of paying attention to watching behaviors in live streaming, our study extends the research to Danmu sending behavior on the live streaming context, which has mostly been ignored (Zhang & Sun, 2018). Most studies on live streaming focus on motivation behind watching behavior (Chen & Lin, 2018; Hilvert-Bruce et al., 2018; Hu et al., 2017; Sjöblom & Hamari, 2017) and broadcasting motivation of the streamer (Zhao et al., 2018). And research on Danmu examines the watching behavior of Danmu (Zhang & Sun, 2018) and outcome of Danmu function (Fang et al., 2018). We contribute to Danmu and live streaming literature by examining the antecedent of active Danmu participation from the effectance theory perspective.

Second, we contribute to Danmu literature by investigating the underlying psychological mechanism behind active Danmu participation in live streaming. Through effectance theory perspective, we identify two kinds of effectances – Danmu effectance and live streaming effectance – that influence users' active Danmu participation in live streaming. Danmu effectance has a significant impact on users' active Danmu participation, and live streaming effectance has direct and indirect effects on active Danmu participation. These empirical findings show the theoretical importance of this study in explaining and predicting future active Danmu participation.

Third, we contribute to effectance theory literature by providing understanding of how technical characteristics

influence the effectance. These results indicate that both time-enhanced and space-enhanced technical features of Danmu in live streaming play a crucial role in promoting user's effectance. Although previous study has noted the important role of system usability on effectance in interactive systems (Klimmt et al., 2012), our research is the first to test the importance of technical characteristics of Danmu in live streaming. The present study found that synchronicity and visibility are essential factors of effectance on live streaming platforms.

Fourth, we extend the application and understanding of effectance theory. Previous studies on effectance are mostly in interactive media such as computer games (Klimmt et al., 2007) and interactive storytelling (Klimmt et al., 2012). This study is the first to apply the effectance theory to study the Danmu phenomenon in live streaming. In addition, this study contributes to effectance theory literature by providing a classification of effectance from the effect on object and exploring the relationship between different effectances. Specifically, we found that live streaming effectance is positively associated with Danmu effectance.

6.3 Practical Implications

Drawing on findings from this study, we also provide some guidelines for practitioners. First, facing the fierce competition among lots of live streaming platforms, live streaming providers should understand how to improve the active behavior of users. Active Danmu participation is essential for the development. To predict the degree to which the users send Danmu comments, live streaming providers and the streamer should pay attention to two effectances. For example, the streamer can react to the suggestion by the Danmu comments sent by the user, which can boost the users' perceived influence on the content of the live streaming, namely the live streaming effectance. And the live streaming platforms should take strategic actions such as setting of Danmu display to enhanced users' perceived influence on Danmu, namely Danmu effectance. Consequently, it will promote the active Danmu participation of users and thus will be beneficial for the interaction between users and the steamer.

Second, because technical characteristics of Danmu are good indicators of the two effectances, live streaming providers should manage the technical characteristics of Danmu and examine the effects of these factors on users' effectance. Several measures can be employed on platforms to increase the synchronicity and visibility. For example, practitioners can increase synchronicity and visibility by providing the smooth and stable bandwidth for users to send real-time and visible Danmu comments. Consequently, users can easily succeed in exerting influence on the content of Danmu or live streaming and have an experience of effectance.

6.4 Limitations and Future Research

This study also has its limitations. First, as an initial examination of active Danmu participation in live streaming, we consider a limited set of variables. The research model accounted for 38.3% of the variance of the active Danmu participation, indicating that some other factors not considered in the model may also affect users' active Danmu participation. Other important antecedents of active Danmu participation can be explored in future research. Second, actual Danmu sending behavior was not incorporated in the research model, future research can consider objective measurement of active Danmu participation. Third, although Douyu is a popular live streaming platform in China, it represents only one type of live streaming. Future research may extend our model to other types of live streaming, such as Huya or Inke, which are other live streaming platforms with huge user bases in China. Fourth, different live streaming genres, such as music, game, sports, etc., may have different patterns of active Danmu participation. Moderating factors such as the type of content of live streaming may provide a more comprehensive understanding of Danmu sending behavior in different situations. Future research can explore these moderators. Finally, there may be different psychological mechanism behind different patterns of active Danmu participation. Future research can identity different patterns of active Danmu participation and explore the outcomes of active Danmu participation.

7 Conclusion

This study investigated the roles of technical factors of Danmu (synchronicity and visibility) on users' effectances consisting of Danmu effectance and live streaming effectance and how such factors further influence their active Danmu participation on live streaming platforms. This study represents an important advancement in our theoretical understanding of the effectance on active Danmu participation in live steaming. These findings help live streaming providers focus on the important role of

effectances and pay attention to technical characteristics of Danmu to promote users' active Danmu participation on live streaming platforms.

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Appendix A

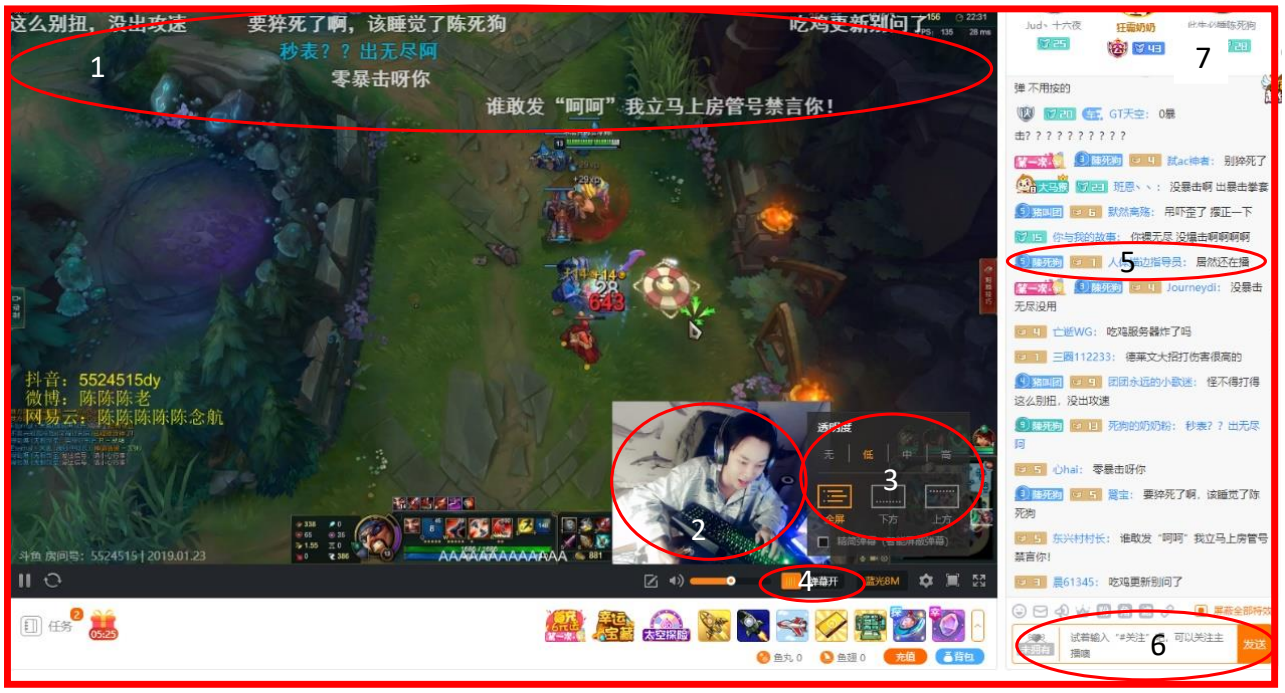

Figure 1. **Example image of a live streaming with default Danmu function on Douyu (www.douyu.com)**
1: Danmu comments: move from right to left.
2: Streamer Window: the live display of streamer
3: Danmu settings: users can modify the transparency and location (top or bottom of the screen or full screen) of Danmu.
4: Danmu Switch: users can turn off the Danmu function.
5: Users Information: the name and the level of the users with their comments
6: Send Danmu: the function of sending Danmu comments.
7: Live Streaming Window: the screen of the live streaming

Appendix B

Questionnaire Items

Construct	Items	
Synchronicity Liu (2003)	S1	When watching live streaming, the website processes my Danmu inputs very quickly.
	S2	When watching live streaming, seeing Danmu sent by other viewers is very fast.
	S3	When watching live streaming, I am able to see others' Danmu without any delay.
	S4	When watching live streaming, the website is very quick in responding to my Danmu inputs.
Visibility Karahanna (1999) and Moore (1991)	V1	When watching live streaming, Danmu is very visible to all viewers in the live streaming environment.
	V2	When watching live streaming, anyone can see my Danmu comments overlaid on the live streaming.
	V3	When watching live streaming, it is easy for me to see others' Danmu comments fly through the live streaming.
	V4	When watching live streaming, other audiences would notice it on the live streaming if I send a Danmu comment.
Danmu effectance Klimmt (2007)	DE1	When watching live streaming, other viewers respond to my Danmu comments.
	DE2	When watching live streaming, I can recognize which Danmu I have caused with my inputs.
	DE3	When watching live streaming, other viewers reply to my Danmu comments.
Live Streaming effectance Bründl (2017) and Klimmt (2007)	LSE1	When watching live streaming, the streamer reacts to my Danmu comments.
	LSE2	When watching live streaming, I think I can push the live streaming forward.
	LSE3	When watching live streaming, I can recognize which content of live streaming I have caused with my inputs.
	LSE4	When watching live streaming, I have the feeling that I can achieve something in the live streaming through my Danmu comments.
Active Danmu participation Gharib (2017) and Kuem (2017)	ADP1	When watching live streaming, I often send Danmu comments.
	ADP2	When watching live streaming, I am active in communicating by sending Danmu comments.
	ADP3	When watching live streaming, I try to participate in discussion through my Danmu comments.
	ADP4	When watching live streaming, I attempt to take an active part in Danmu.
	ADP5	When watching live streaming, I regularly reply to posted Danmu comments.
	ADP6	When watching live streaming, I regularly post Danmu comments to respond to the streamer.

Appendix C

Factor Loadings and Cross Loadings in PLS

	Synchronicity (S)	Visibility (V)	Danmu effectance (DE)	Live streaming effectance (LSE)	Active Danmu participation (ADP)
S1	**0.816**	0.493	0.284	0.268	0.294
S2	**0.758**	0.443	0.237	0.202	0.297
S3	**0.711**	0.339	0.223	0.229	0.275
S4	**0.836**	0.436	0.316	0.302	0.308
V1	0.482	**0.803**	0.354	0.294	0.356
V2	0.427	**0.841**	0.388	0.314	0.345
V3	0.417	**0.712**	0.312	0.226	0.334
V4	0.441	**0.840**	0.440	0.401	0.428
DE1	0.290	0.379	**0.797**	0.476	0.395
DE2	0.271	0.353	**0.791**	0.502	0.402
DE3	0.270	0.406	**0.824**	0.524	0.487
LSE1	0.297	0.353	0.496	**0.749**	0.405
LSE2	0.253	0.352	0.518	**0.843**	0.449
LSE3	0.263	0.312	0.540	**0.814**	0.483
LSE4	0.211	0.222	0.405	**0.762**	0.352
ADP1	0.308	0.391	0.405	0.430	**0.811**
ADP2	0.324	0.416	0.456	0.480	**0.871**
ADP3	0.333	0.384	0.411	0.388	**0.791**
ADP4	0.320	0.390	0.389	0.411	**0.845**
ADP5	0.240	0.343	0.484	0.468	**0.738**
ADP6	0.288	0.293	0.417	0.398	**0.764**