“I Am Concerned, But…”: Streamers’ Privacy Concerns and Strategies In Live Streaming Information Disclosure

YANLAI WU*, University of Central Florida, USA
YAO LI, University of Central Florida, USA
XINNING GUI, Pennsylvania State University, USA

Live streaming is a popular synchronous social media platform that allows users to disclose information to vast audience in real time. It has been increasingly studied in recent years for its unique functions of disseminating user-generated content, enriching streamers’ self-presentation, curating online social interactions and fostering online communities. However, little research has been done to explore the privacy issues in live streaming. In the present paper, we aim to understand streamers’ privacy concerns and strategies in their information disclosure on live streaming. From an interview study with 20 streamers, we found that they expressed concerns and carefully managed their information disclosure based on whether the disclosure would enhance or weaken their attractiveness to the audience and whether it would disturb their interpersonal boundary with the audience. They adopted various technical and behavioral privacy management strategies to cope with their concerns, but encountered a series of usability and cognitive burdens. Based on the findings, we present design implications to improve the privacy management on live streaming.

CCS Concepts: • Security and privacy → Social aspects of security and privacy; Human and societal aspects of security and privacy;

Additional Key Words and Phrases: privacy; live streaming; streamer; information disclosure; social media

ACM Reference Format:

1 INTRODUCTION

Live streaming is a unique form of social media that allows users to share content and interact with their audience directly in real time [85]. Due to the improved network bandwidth and widespread high-definition cameras on various devices, live streaming has become increasingly popular [19, 29, 50, 54, 55]. For example, Twitch, the largest live streaming platform in the US, has 41.5 million users and viewers spent 6.34 billion hours watching Twitch in the first quarter of 2021 [15]. DouYu, the largest of its kind in China, owned 163.6 million monthly active users in 2019 [74], which was 23.6 million monthly active users more than Twitch during the same period [100].

Streamers adopt various practices to present themselves to the audience, such as displaying distinct personal characteristics [30, 82], dressing themselves decently [48], tailoring streaming content to the audience [48], adding entertaining stories, and maintaining social media content outside
live streaming [54, 69, 85]. As personal information disclosure is a primary way of self-presentation [21], it is inevitable that streamers would disclose large amounts of personal information when utilizing these strategies, which could lead to privacy issues. There has been news that reports how streamers’ real names, home addresses, and identities were accidentally revealed in live streaming, causing their privacy and security to be threatened by vicious viewers [23, 28].

However, few studies have investigated streamers’ privacy concerns and practices in their live streaming information disclosure. Understanding the privacy issues that streamers have encountered is important because the privacy management in live streaming is complicated by the performance-driven, socioeconomic, real-time, on-camera and public nature of live streaming. This may lead to unique and complex practices and challenges in privacy management that do not exist on traditional social media: First, streamers’ information disclosure has socioeconomic implications. It is part of the content that streamers create, which is critical for them to draw and retain an audience (e.g., by making viewers feel entertained) and make revenue [46, 71]. Streamers might struggle between privacy protection and content creation. Second, the information production and consumption on live streaming happen concurrently, which means that privacy management strategies that are commonly used on asynchronous social media, such as previewing shared content and withdrawing unwanted content, may not be successful on live streaming. Third, streamers are usually on camera instead of presenting themselves as avatars or anonymous profiles, while the audience is usually anonymous [86]. Streamers’ identifiable information is exposed and could potentially cause privacy risks, such as stalking and harassment. Lastly, live streaming is mostly open to the public audience. It may entail challenges for streamers to control the live audience and gauge who will have access to their disclosed information. In summary, streamers might face new types of privacy issues and challenges in information disclosure that might not exist on traditional asynchronous social media. It is important to explore such potential issues and understand how to design in order to support online streamers’ privacy management.

The present study aims to investigate streamers’ privacy concerns and strategies with information disclosure on live streaming platforms, which will untangle the intertwined relationships among privacy management, content creation, and revenue generation and uncover the privacy challenges in real-time information as disclosed to the public. Specifically, we seek to answer the following research questions:

**RQ1**: What privacy concerns do streamers have in live streaming?

**RQ2**: What are the coping strategies that streamers adopt to manage their information disclosure in live streaming?

To answer the research questions, we conducted 20 semi-structured interviews with streamers. We found that streamers struggled between privacy protection and attractiveness maintenance. Certain information disclosure could make streamers’ performance attractive to the public audience, but raised significant privacy issues for streamers, such as over-exposure of sensitive personal details and disturbance of their boundary with public audience. They thus adopted various privacy management strategies both technically and behaviorally to mitigate these concerns in order to make a trade-off between attractiveness and privacy cost. Based on these privacy challenges reported by our interviewees, we put forward the design implications for live streaming platforms. Our contributions are three-fold: 1) we provide an empirical account of privacy challenges in a novel context - live streaming; 2) we investigate streamers’ attitudes and practices in privacy management during the live performance creation, which advance our understanding of information sharing in live streaming; 3) we suggest design implications for privacy support to reduce streamer’s privacy concerns and support their privacy management.
2 RELATED WORK

2.1 Privacy on Social Media

Information disclosure describes one’s privacy regulation behavior, namely how one attempts to control his or her information flow to others. Altman defined privacy as the selective control of access to the self or one’s group, and self-definition (i.e., what is me and not me) as a central goal of privacy [2]. He argued that privacy regulation served a set of functions to meet people’s needs in self-definition in the social world: 1) constructing self-identity, including one’s definition of self, capabilities, and limitations. This function is similar to Westin’s personal autonomy [93]. Self-identity is the ultimate goal of privacy regulation because regulating access to the self or others allows people to develop a sense of individuality. 2) regulating one’s interaction boundaries with others in the social environment, which was also identified by Westin as “limited and protected communication” [93]. Regulating boundary refers to how people set boundaries between themselves and others to achieve a desired balance between openness and closeness so that they can obtain important information about their social environment and construct a social definition of the self. 3) assessing one’s experience with others and formulating future behaviors, which is close to Westin’s “self-evaluation” [93]. It refers to how people individually review information from interaction with others so that they can develop reflection, assessment, and interpretation of themselves in relation to others. These three functions explain why people need privacy and what social needs privacy regulation serves.

Extensive research has extended Altman’s privacy regulation theory in the context of social media and found many privacy issues arising because the above privacy functions are not functional and users’ social needs regarding self-definition are not met on social media. First, the potential of exposing large amounts of personal information [27] and the collapse of different types of social contexts [62] make it challenging for users to construct their desired self-identity on social media. Research has shown that users were not able to effectively maintain separate parts of their identity on social media, such as their professional identity [83], cultural identity [44], peer identity [1, 6], political/religious identities [62], and gender/sexual/racial identities [11], due to the challenges in managing information flow under different social contexts on social media. Second, the lack of effective audience control techniques makes it difficult for users to regulate their interaction boundaries with others on social media. For example, several studies reported that users struggled with the boundaries between personal social networks and professional life [44, 67, 83], weak ties [84], unwanted relationships [49, 77], and public space [1, 59, 90] on social media.

Research has reported various strategies that users adopt to manage their social identities and regulate their boundaries with others on social media. Most prior work on identity management was built on Erving Goffman’s theory which frames identity management as theatrical performance [5]. When interacting with others, people attempt to selectively disclose their information and highlight the content that can deliver desired impressions, like the performers who selectively present information and act to the audiences to maintain their frontstage appearances. They also manage the expression of self-identity by projecting different personas depending on the audience and broader context. For instance, Twitter users target tweets toward their perceived audience’s interest and deliberately avoid topics that followers might not agree with [62]. Facebook users prefer to post group photos that show one’s social connectedness and popularity [102]. Other social media users also create multiple profiles so that they can present themselves in different ways [61]. Regarding boundary regulation strategies, Altman outlined several coping mechanisms that individuals employed in the offline setting to achieve desired interpersonal boundaries, such as verbal communication (i.e., language styles, voice dynamics, etc.), non-verbal communication (i.e., blocking, averting direct eye contact, etc.), and environmental mechanisms (i.e., shutting the door.
keeping distance, etc.) [2]. Based on these mechanisms, researchers have reported various boundary regulation strategies on social media, such as censoring oneself [16, 81], blocking unwanted contacts [95], withdrawing unwanted content [94], segregating audience [37, 92], negotiating with others [14], and compromising [94].

In sum, previous social media privacy literature found various concerns and strategies that users have when regulating their boundaries and managing their identities on social media. However, most social media examined are asynchronous, which means that the content production and consumption are in sequence rather than in real-time. Such findings may not apply to privacy management on live streaming platforms where information sharing and consuming are in real-time. For instance, in asynchronous social media, users have a chance to self-censor, edit, and withdraw their posts, which is unlikely in real-time information broadcasting. Furthermore, live streaming is mostly open to public viewers who can join the live streaming and interact with the streamers in real-time [30, 34]. Thus, it is challenging for streamers to get familiar with and tailor their information-sharing to the current viewers in real time. Building on the rich findings on privacy concerns and management on asynchronous social media, our study aims to extend Computer-Supported Collaborative Work (CSCW) and Human-Computer Interaction (HCI) research on social media privacy by untangling live streamers’ privacy concerns and management and exploring design implications to support their privacy management.

2.2 Related Work on Live Streaming

Previous work on live streaming has shown that performance creation is a central element in live content generation. Research has shown that streamers not only present the content, but also perform their desired identities to the audience [48]. Attractive performance in streamers’ live broadcast can include talented performance [35, 36, 57], demonstrations of skills [36, 80], tours and sightseeing [36, 57], outdoor activities [55], gameplays [35, 57], and other aspects of life. Attractive performances can bring more audience who might give monetary compensation to the streamers [8, 24, 99]. Streamers recognize the value of their performance and can potentially make a living from the monetary rewards from the audience [53, 99]. Additionally, through creating performance, streamers can develop their “personal brand” [85], become famous [24], disseminate knowledge [54], and build online communities [34].

To better understand the attractiveness in streamers’ live performances, we borrow McCroskey and McCain’s framework [63] about interpersonal attraction. McCroskey and McCain’s work classifies interpersonal attraction into three dimensions: physical, task, and social attraction [63]. Physical attraction is determined by a person’s physical features. The more physically attractive one is, the more sociometrically popular. Task attraction refers to our perceptions of whether a person can assist us to get what we desire. People tend to be attracted to those who are capable of and willing to fulfill their needs and achieve their goals. Social attraction is the socioemotional dimension of interpersonal attraction, which reflects a social or personal liking property. In other words, social attractiveness implies whether a person is pleasant to be with and could potentially become a friend.

Self-presentation is a common and important strategy for streamers to maintain attractiveness in live content broadcasting. Several studies have investigated streamers’ self-presentation strategies in live streaming. Generally, streamers would be on camera, adjust the aesthetics (dressing, hairstyle, and appearance), decorate physical functions (vocal and physical), research on background information/knowledge to prepare for their performance, share personal stories and opinions, add entertaining commentary and casual chat, and highlight distinct personal characteristics, styles and personalities [48]. Another study on female and LGBTQ streamers similarly reports that streamers develop two core strategies to present themselves through performance, including manipulating
webcams and microphones to highlight face and voice and purposely managing clothing and appearance [25]. Streamers also utilize social media outside the live streaming platforms to present themselves to viewers, such as sharing their social media profiles, posting about their skills and sending pre-recorded videos to audience through direct messages [54].

Since self-presentation involves large amounts of personal information disclosure, potential privacy issues might arise in streamers’ performance. However, the majority of privacy research in the context of live streaming has focused on bystanders’ privacy concerns, namely when people are streamed by others. When streams occur in public spaces, bystanders can be easily captured in live videos [55], thus having concerns about identities being exposed to an unknown audience [78]. Another study on video game live streaming also reported bystanders’ concerns with accidentally disclosing personal information and causing unwanted consequences [50]. Thus, bystanders adopt strategies such as withholding sensitive information and collaborating/negotiating with the streamers to protect their personal information from being streamed [50]. To solve the privacy issues of bystanders, researchers have proposed to obscure details of privacy-sensitive objects in live videos [31]. While these prior studies focused on bystanders in live streaming, few studies have discussed streamers’ privacy issues. One study briefly described the possibility that outdoor live streamers could accidentally disclose their passport numbers, credit card numbers, and vehicle license plates while streaming [55]. Another study indicates that there is a special group of streamers called “Nakanohitos” who dub for VTubers, and tend to not disclose their personal identity to the public due to privacy concerns and corporations’ policies [56].

Other aspects in the live streaming literature cover viewer’s watching experience, live content moderation and live streaming community fostering. Prior work has shown that the viewers watch live streams to relax [57, 79], kill time [43, 57], keep up with “fashion” [52], make more friends [32], communicate with others [47, 57, 79], improve skills [13, 26, 79], find a community [12, 30], gain new knowledge [53, 54], or seek the feeling of company [57]. To motivate viewers to keep coming back to the live streams, streamers commonly make efforts to interact with the viewers and maintain active online communities [79]. Streamers’ personalities, attitudes, and values decide who will stay in their communities [30, 79]. In order to reduce inappropriate content in live streaming, streamers adopt various technical and behavioral strategies to moderate the live chat in their streams [9, 43, 97, 98]. For example, streamers adjust the pace of the game to meet audience’s expectations [43]. Streamers on Twitch take advantage of moderation tools such as chat control, viewer control, content control, and setting control to manage their channels and better interact with their audience [9].

In sum, prior work shows that streamers are prone to present attractive performances to their audience, which could generate financial revenues for streamers. Thus, streamers adopt various self-presentation strategies so that their performance attracts, satisfies, and entertains the audience. However, little attention has been focused on streamers’ privacy concerns and practices in live performance creation. As streamers disclose large amounts of personal information in producing live performances, their privacy concerns and strategies might interplay with their desire to generate an attractive performance and to seek financial revenues. They might encounter tensions between content creation and privacy protection. Additionally, while viewers mostly remain anonymous, streamers share a great deal of identifiable information in live streaming, such as their physical appearance and physical locations, which could potentially cause privacy risks, such as boundary disruption, stalking and harassment. Thus, investigating the privacy issues in streamers’ content creation is of great importance. Our work will fill the gap by studying streamers’ concerns with information disclosure and their coping strategies to manage these privacy concerns.
3 METHODOLOGY

3.1 Study Site

We conducted 20 semi-structured interviews with DouYu streamers in October 2020. We chose DouYu as the study site because: 1) DouYu is one of the most popular live streaming platforms and has been studied several times in prior work [101, 103]; 2) DouYu shares many privacy and information disclosure features with other popular live streaming platforms (see Table 1 for a detailed comparison). Similar to other live streaming platforms, streamers on DouYu are mostly equipped with a webcam, a mic, and a computer, and/or a mobile phone to run the streaming platform. Streamers are allowed to: 1) enable webcam anytime to share their video images; 2) enable/disable their video/audio sharing, start/pause streaming, and enable/disable screen sharing at any time; 3) apply “beauty filter” to enhance their images in the video, such as smoothing the skin, tuning the skin tones, adjusting the size of the image, and adding filters or other effects; 4) enable the “mirror my video” feature when they want to check their looks in the live video from the audience view; 5) set up a “virtual background”, which is to display an image as the background in the live video and thus hide the streamers’ real background; 6) add an “overlay”, namely inserting an image or texture to hide the information on the screen sharing that they want to block from the audience; 7) control the specific content to be displayed on screen and audio sharing (also called “manage sources of streaming content”), such as which screen, software, webpage, and screen zones to be live broadcasted to the audience, and which sound of the microphone, background music and audio chat to be delivered in the audio sharing. These seven features are listed in Table 1. Both overlay and source management are effective for managing partial information disclosure. If streamers want to restrict the entire screen sharing, the most convenient way is to pause stream, which freezes the entire video broadcasting. However, this feature does not pause the ongoing audio sharing. As all these features can also be found on other popular live streaming platforms, we thus concluded that the findings based on DouYu are generalizable.

The channels on DouYu are mostly open to the public audience. Audiences can watch streams either in live streaming mobile apps or on websites, with the streamers’ video image, screen sharing, and audio at the same time. The live chat box is where streamers and audiences communicate in real-time. The content posted in the live chat is called Danmaku and flows on the screen [55]. Apart from the interactive live chat, streamers can also receive virtual gifts from their audience. Virtual gifts, worth up to different values from cents to hundreds of dollars, are shown as animated cartoons on the live stream interface and are visible to the audience [57]. In sum, DouYu is a popular live streaming platform and shares many disclosure management features with other popular live streaming platforms. We thus chose it as our study site.

<table>
<thead>
<tr>
<th>#</th>
<th>Features</th>
<th>DouYu</th>
<th>Huya</th>
<th>YouTube Live</th>
<th>Facebook Live</th>
<th>Twitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Enable webcam</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Video/audio sharing</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Pause stream</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Screenshare</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Beauty filter</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Mirror my video</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Virtual background</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Add overlay</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Manage sources of streaming content</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 1. Comparison of disclosure-related features between DouYu and other popular live streaming platforms.
### Table 2. Demographics of Interviewees

<table>
<thead>
<tr>
<th>#</th>
<th>Age</th>
<th>Gender</th>
<th>Occupation</th>
<th>Length of streaming</th>
<th># Viewers</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
<td>Male</td>
<td>Student</td>
<td>5 times</td>
<td>5+</td>
<td>Mahjong</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
<td>Female</td>
<td>Student</td>
<td>3-4 years</td>
<td>300+</td>
<td>Warcraft, PlayerUnknown’s Battlegrounds, Call of Duty</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>Male</td>
<td>Student</td>
<td>15 days</td>
<td>30+</td>
<td>League of Legends, PlayerUnknown’s Battlegrounds</td>
</tr>
<tr>
<td>4</td>
<td>28</td>
<td>Male</td>
<td>Civil Servant</td>
<td>1 year</td>
<td>20+</td>
<td>JX3 (game)</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>Female</td>
<td>Full-time Streamer</td>
<td>5 years</td>
<td>600+</td>
<td>Singing, Chatting, Casual games</td>
</tr>
<tr>
<td>6</td>
<td>22</td>
<td>Male</td>
<td>Freelancer</td>
<td>1 year</td>
<td>200+</td>
<td>Dota</td>
</tr>
<tr>
<td>7</td>
<td>26</td>
<td>Male</td>
<td>Teacher</td>
<td>3 months</td>
<td>5+</td>
<td>Hearthstone</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>Male</td>
<td>Student</td>
<td>2 years</td>
<td>80+</td>
<td>Hearthstone</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>Female</td>
<td>Student</td>
<td>3 years</td>
<td>20,000+</td>
<td>Overwatch, PlayerUnknown’s Battlegrounds</td>
</tr>
<tr>
<td>10</td>
<td>22</td>
<td>Male</td>
<td>Student</td>
<td>Half year</td>
<td>300+</td>
<td>Honor of Kings</td>
</tr>
<tr>
<td>11</td>
<td>22</td>
<td>Female</td>
<td>Student</td>
<td>Half year</td>
<td>50+</td>
<td>Singing, Chatting</td>
</tr>
<tr>
<td>12</td>
<td>18</td>
<td>Male</td>
<td>Crew</td>
<td>3-4 months</td>
<td>10,000+</td>
<td>Honor of Kings</td>
</tr>
<tr>
<td>13</td>
<td>27</td>
<td>Female</td>
<td>Full-time Streamer</td>
<td>2 months</td>
<td>10+</td>
<td>Singing, Chatting</td>
</tr>
<tr>
<td>14</td>
<td>28</td>
<td>Male</td>
<td>Software Engineer</td>
<td>1 month</td>
<td>8+</td>
<td>Singing, Gwent: The Witcher Card Game</td>
</tr>
<tr>
<td>15</td>
<td>23</td>
<td>Male</td>
<td>Student</td>
<td>3 months</td>
<td>1000+</td>
<td>League of Legends</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
<td>Male</td>
<td>Student</td>
<td>1 month</td>
<td>70,000+</td>
<td>PlayerUnknown’s Battlegrounds, League of Legends</td>
</tr>
<tr>
<td>17</td>
<td>30</td>
<td>Male</td>
<td>Entrepreneur</td>
<td>Half year</td>
<td>5+</td>
<td>Warcraft, PlayerUnknown’s Battlegrounds, League of Legends</td>
</tr>
<tr>
<td>18</td>
<td>22</td>
<td>Female</td>
<td>Student</td>
<td>16 days</td>
<td>1000+</td>
<td>Chatting</td>
</tr>
<tr>
<td>19</td>
<td>29</td>
<td>Male</td>
<td>Financial Analyst</td>
<td>1 year</td>
<td>10-20+</td>
<td>Hearthstone</td>
</tr>
<tr>
<td>20</td>
<td>23</td>
<td>Female</td>
<td>Student</td>
<td>2 months</td>
<td>10,000+</td>
<td>Apex Legends</td>
</tr>
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<td>21</td>
<td>29</td>
<td>Male</td>
<td>Computer Scientist</td>
<td>1.5 years</td>
<td>500+</td>
<td>Algorithm Teaching</td>
</tr>
<tr>
<td>22</td>
<td>27</td>
<td>Male</td>
<td>Teacher</td>
<td>2 years</td>
<td>700+</td>
<td>Casual Games, Chatting, Outdoor Activities</td>
</tr>
<tr>
<td>23</td>
<td>22</td>
<td>Female</td>
<td>Student</td>
<td>1 year</td>
<td>200+</td>
<td>Casual Games</td>
</tr>
<tr>
<td>24</td>
<td>20</td>
<td>Female</td>
<td>Full-time Streamer</td>
<td>2 years</td>
<td>1000+</td>
<td>Casual Games</td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td>Female</td>
<td>Full-time Streamer</td>
<td>1 year</td>
<td>3000+</td>
<td>Singing, Chatting, Casual Games</td>
</tr>
</tbody>
</table>

#### 3.2 Data Collection

The 20 interviewees were recruited through three methods: 1) posting of recruitment information in the university WeChat groups (the most widely adopted social media in China), through which four participants were recruited; 2) posting of recruitment ads on Weibo (the most popular microblogging website in China) under the DouYu-related topics, from which three participants were recruited; 3) thirteen additional participants were recruited through snowball sampling by the referrals of the author’s personal social network and streamers of those who have been interviewed. All the recruited streamers were over 18-years of age and had experience in live streaming (see Table 2 for the interviewees’ demographic information). We carefully considered full-time/part-time, length of streaming and number of viewers when recruiting participants because we wanted to explore privacy concerns and strategies for different types of streamers. The participants we recruited included both full-time and part-time streamers, those who have been streaming for a few days to several years, and streamers who have just a few viewers to those who have tens of thousands. The interviews were conducted through WeChat audio chat in Mandarin. Each interviewee was compensated 70 (about 10 dollars) which was sent through WeChat Red Pocket (a money transfer function on WeChat). The IRB of this interview study was approved by the university and each interviewee was informed of the research purpose and procedure prior to being interviewed.
Each of our semi-structured interviews took between 30 to 60 minutes. Each interview started with some general questions to build rapport with participants, such as the length of their live streaming experience, the content they used to stream, and their motivations to stream. We then asked about their information sharing during live streaming. We put emphasis on probing in regard to what information they liked to share, what information they preferred not to share, their experience and concerns of information disclosure, and their strategies on managing information disclosure. The specific interview questions can be found in Appendix A. The interviews were recorded for transcription purposes, with consent from each interviewee. After the authors transcribed the interviews and anonymized identifiable details, the audio recordings were deleted.

3.3 Data Analysis
In conducting our research we applied thematic analysis [7] to evaluate our interview data using an inductive approach [58]. It’s important to note that all the researchers who participated in data analysis were familiar with live streaming and privacy research. Our process began by scrutinizing the data then individually noting initial ideas related to information disclosed. Next, we compared our initial data codes and combined them into a single list through rounds of discussions leading to a total of 89 codes. According to the initial coding, we advanced our analysis to gather the overarching themes from our codes in extensive rounds of discussion. We also went back and forth between the generated themes and the dataset to collate codes into potential themes and sub-themes. The next step was to refine the themes and sub-themes to ensure internal homogeneity and external heterogeneity [58]. The final thematic map consists of three primary themes: privacy concerns in live streaming, privacy strategies in live streaming, and challenges streamers have encountered in privacy management. All the quotes from our participants were translated into English when reporting the data in the paper. To protect our participants’ privacy, we use numbers to denote different interviewees.

4 STREAMERS’ PRIVACY CONCERNS
Generally, we find two categories of privacy concerns that participants had experienced during their information disclosure in live streaming. First, streamers were concerned that disclosing or withdrawing certain personal information might undermine their attractiveness to the audience. Second, streamers had concerns in regard to their interpersonal boundary with the audience. We elaborate on these concerns in the next two sub-sections.

4.1 Tensions Between Privacy and Attractiveness
Our participants reported two major tensions between privacy and attractiveness in live streaming. First, while they were worried that disclosure of certain information, such as physical features, body movement skills, and personal preferences, would reveal too much personal information to the audience, they found such information made their live performance more attractive, thus decided to compromise their privacy in exchange for attractiveness. Second, certain personal information, though authentic about streamers, raised concerns to streamers because authentic information would unfavorably impact their attractiveness.

Previous research has found that perceived media character attractiveness influences viewer responses to media personae, thus playing a key role in parasocial interactions [39, 40, 73]. In our study, our streamer participants, as media personae themselves, acknowledged the importance of demonstrating their attractiveness as a way to attract and retain viewers, while at the same time struggled with the tensions between privacy and attractiveness.

For our participants, there were complex tensions between preserving private information and constructing such attractiveness. They were aware that disclosing certain personal information
would attract audience, which would lead to more monetary income (as most live streaming platforms allow audiences to give monetary gifts to the streamers) and more entertaining content. For instance, P10, a male 22-year-old student who had streamed for six months on DouYu with more than 300 viewers (shortened as “male, 22, student, half year, 300+”), reported, “If I have a lot of audiences, one day I make an impressive kill (in the game) and they (audience) are likely to send me gifts. Then my ranking (on DouYu) will go up. It means more people will be attracted to my channel. There will be more chat, more interaction, more subscriptions, and of course more gifts.”

However, sharing such personal information oftentimes contradicted their privacy attitudes and concerns. They had to make a trade-off between privacy and attractiveness. In this section, we report three types of tensions between streamers’ privacy and attractiveness, inspired by previous work’s classifications of interpersonal attractiveness [40, 42, 63], in the next three subsections.

4.1.1 Tradeoffs Between Privacy and Physical Attractiveness. Physical attractiveness refers to the appealingness of a person’s outer appearance [40, 42, 63]. Six participants (P1, P2, P5, P10, P14, P15) ranging from new streamers to experienced streamers explicitly explained to us that they were concerned with disclosing information about their physical features, such as looks, appearance, apparel, figures, voice and actions, during live streaming. They felt such disclosure exposed too much personal information to the audience. Other participants, especially most of the female streamers (P9, P11, P18, P20) mentioned that they hesitated to share such information as well. However, after failing to attract audience and observing other successful streamers, all those participants realized that such information could show their physical attractiveness to the audience and thus attract more viewers and increase their financial revenues. Therefore, most of them eventually decided to disclose their physical appearance and even enhance their appearance (e.g., by using makeups). For example, P5 (female, 20, full-time streamer, 5 years, 600+), a female streamer, described:

I don’t really want to be on the webcam. I mean who wants to? I feel like I have nowhere to hide (when the webcam is on). Everyone is staring at me. I don’t like that. I didn’t turn on my webcam at first. Then there was no viewer at all. So I thought about it. You know, those people on TV show their faces all the time. Of course, they have pretty face. But it’s about interaction, right? If you treat it (live streaming) like a profession, showing your face means you respect your audience.

Even when they decided to trade privacy for physical attractiveness, participants were worried that their real physical appearance was unsatisfying to audiences, which might negatively impact their attractiveness. They observed that audiences would give more monetary gifts, attention, and comments to streamers who were better looking and treated less good-looking streamers with less enthusiasm. Thus, they put effort into improving their physical attractiveness. As P5 continued her story:

I remember when I turned on my webcam for the first time, I was looking like a mess. I just hated makeups and dresses. After like three years, I found that I couldn’t compete with other streamers. Other streamers were pretty and got tons of gifts, followers and Danmakus. I was like really lame. My viewers treated me like a random person. You know, people would be nice to you if you got a pretty face. I am a girl. I don’t look ugly. Why should I give up? So I began to dress up before live streaming.

In these two quotes, P5 articulated how and why she gave up privacy in exchange for physical attractiveness. As a streamer, she felt that she had no choice but to trade privacy for attractiveness in order to compete with other streamers regarding the size of audience and financial revenues.

In addition, most of our participants, including most of the female streamers (P2, P5, P9, P11, P18, P20) perceived that disclosing satisfying physical features in live streaming was especially necessary for female streamers, based on their experiences and observations. According to P2 (female, 28, student, 3-4 years, 300+), another female streamer:}
I don’t want to turn on webcam. But it is very necessary for girls. Girls get more audience if they are on camera. You know Xiao TuanTuan (a famous female streamer on DouYu)? She used to attract audiences with her voice and humor. But she is even on camera now… I remember when I first streamed, I only displayed my hands and keyboard (not sharing face in the webcam). Then audiences commented, “why does she hide her face” “Is it because she looks ugly.” You know. They are just coming for a pretty face.

P2 emphasized the importance of disclosing looks for female streamers in order to attract a good size of audience, even though such information sharing revealed more personal details than disclosing other types of physical features. When she was only willing to share her voice and hands in live streaming, she often encountered unfriendly audiences which made her feel frustrated. Such situations rarely happened to our male participants, as P17 (male, 30, entrepreneur, half year, 5+), a male streamer, told us, “Few male streamers use webcam in live streaming unless they need to do some singing, dancing and outdoors. There is a big difference between male and female streamers in using webcams. Female streamers have to do that.”

4.1.2 Tradeoffs Between Privacy and Task Attractiveness. Task attractiveness refers to a person’s success in accomplishing tasks [40, 63] desired by the audience. People tend to be attracted to those who are capable of and willing to fulfill their needs and achieve their goals [63]. To achieve task attractiveness, some of our participants chose to disclose certain personal information to prove that they were capable of doing the tasks they streamed. For instance, P14 disclosed his educational background in psychology to demonstrate that he was better at solving mental health related issues than other streamers. Many audiences often came to his live streams and asked for advice: “They called me the professor because I know lots of stuff. I told them I had a background in psychology and that delivered them a message – I have expertise and I am more professional than other streamers.”

Other times, streamers performed certain tasks only for a particular audience, and had privacy concerns that their performances were observed by a different audience. For instance, the audience sometimes would request streamers to perform certain types of tasks, such as doing some sexually suggestive actions, which streamers did not feel comfortable doing because of privacy concerns. Several female streamers told us that they were unwilling to disclose their gender, body movement skills (i.e., twisting, dancing and bouncing), intimate personal details, and personal preferences in the content created for live performance. They were worried that such information disclosed might cause discriminatory harassment from the audience to them and enhance people’s existing stereotypes and biases towards female streamers. However, they were aware that the audience expected to see these types of tasks in their streams. Some of them eventually compromised as such disclosure was effective to enhance task attractiveness and fulfill the audience’s needs. Such scenarios were more frequently brought up by female streamers, especially those who had only streamed for a short period of time and were desperate for more audience members. For example, P18 (female, 22, student, 16 days, 1000+), a female streamer who just started to stream on casual talk but had a growing number of viewers, told us:

They (audience) are here for fun. If you do something sexual but not across the line, like dancing a little and twisting your body, they will be very happy. Do I reject it? Well, it’s kinda a show, right? You give them what they want. They won’t ask for too much. Of course, if you are a famous streamer, you don’t have to do that… I am concerned if my friends see me doing that in the streams. I know they watch streams a lot. That will be so embarrassing if they see me there doing those sexual things. You know people already have bias towards female streamers.

4.1.3 Tensions Between Privacy and Social Attractiveness. Social attractiveness implies whether a person is pleasant to be with and could potentially become a friend [63]. Participants reported tension between protecting private information in regard to their social identities and maintaining
social attractiveness. Certain personal details about streamers’ social identities, such as real-world relationships, social life, interests, and opinions, could make streamers socially attractive and likable, increasing audience’s interest to socialize, interact and gift with the streamers. However, revealing such personal details might cause unwanted privacy risks to streamers, such as online stalking and bullying. Thus, the streamers had to balance between over-exposure and over-restriction of personal information in the online interaction with an audience to make themselves more socially attractive.

In live streaming, one important way that participants maintained their social attractiveness was to share personal details, including relationships, everyday life, interests, personalities, and opinions. Three participants treated the audience as their friends, thus feeling no point in hiding personal details from the audience, as they believed being honest was important when interacting with friends. For example, P12 (male, 18, crew, 3-4 months, 10,000+) explained “I love sharing everything with my audience. They are my friends. I want to be honest with them. They liked to ask about my relationship, like where we’ve been and what we eat. That’s what friends talk about.”

However, the majority of female participants were concerned with sharing too many personal details with the audience for social attractiveness, especially details about their real-world social relationships. Three female participants expressed concerns about disclosing relationship information in exchange for social attractiveness because it might cause unwanted consequences, such as online stalking and bullying. These participants had different lengths of streaming experience and numbers of viewers. For example, P2 (female, 28, student, 3-4 years, 300+) shared:

They would ask me a lot of questions about my relationships, like when I broke up and what type of guys I am interested in. I usually make up the answers. I won’t tell them the truth… They want to know me better and get close. So they come to my channel more often. But I’m concerned that some of them might get too close, like they feel they have a good relationship with me and ask for my phone number and maybe, you know, stalk me.

In this case, P2 was concerned that disclosing relationship information might cause online stalking. However, such information disclosure could potentially improve her social attractiveness and strengthen her relationship with the audience. Thus, the streamer decided to use a fake response to both maintain her social attractiveness and preserve her privacy.

In addition, participants mentioned the tension between disclosing their authentic social identity and maintaining social attractiveness. Though participants have the desire to be authentic and honest to their audience, they found not all personal details are likable to the audience, such as romantic relationships, living environment and private interests/behaviors (i.e., sexy wallpaper). This information would harm their social attractiveness because it might not be socially desirable. Therefore, they would restrict such information disclosure or even lie about it. For instance, seven participants reported that audiences did not like interacting with or sending gifts to streamers who had already been in a romantic relationship. Hence, these streamers pretended to be single in live streaming. Such situation was more common to female (n=5) than male participants (n=2). For example, P20 (female, 23, student, 2 months, 10,000+) said:

The audience knew I had a boyfriend when I streamed a long time ago. At that time, my boyfriend and I played the League of Legends and we used to sit together when playing and streaming. They called my boyfriend ‘mouse’ because he sometimes helped me play the game when I went to the bathroom. It was really weird, they liked to joke around my boyfriend. Then this time, I got some audience was like ‘if you have a boyfriend, I am not coming’. So I didn’t tell them about my boyfriend. I think they want me to be single. They are not like hoping to develop a romantic relationship with me. But they want to keep some imagination there, you know, like those have for idols.

When P20 frankly shared her relationship with her audience in her previous live streaming, she felt the unfriendly attitude from the audience towards her boyfriend, as her audience made fun of
her boyfriend. Thus, she decided to hide her relationship and to perform a “single girl” identity in her current live streaming to increase the audience’s desire to socialize with and gift her. Based on her experiences, P20 believed that female streamers risked losing social attractiveness if they disclosed their romantic partners because audiences expected the female streamers to be single. In fact, audience members did not plan to be in an actual romantic relationship with the streamers, as in most cases it was infeasible. Nevertheless, they wanted to keep some possibility there, where they could socialize with the female streamers in whichever way they preferred regardless of her actual relationship status. Thus, the streamer decided to hide her relationship and performed as a “single girl” in her live streaming. This indicated that streamers had to withhold certain information disclosure and perform their social identity in order to maintain their social attractiveness.

Although participants tried hard to hide undesirable information from harming their social attractiveness, such information could be accidentally disclosed by their bystanders, such as their families. Two participants, one experienced and one beginner streamer, had encountered such issues. For example, P7 (male, 26, teacher, 3 months, 5+) said:

*My parents would sometimes ask me to clean my room, or talk to me about some family matters, while I’m streaming. It’s like if you got a friend visit you, and your mother asked you to clean your room. It was just so embarrassing.*

In this case, the information that would negatively affect the participant’s social attractiveness was disclosed indirectly by his parents, who appeared in live streaming unexpectedly. The disclosure was unintended, as it was not the parents’ intention to broadcast such information to the audience. But it raised privacy concerns to the streamer knowing they could not fully control undesirable information on their own efforts. Even though they tried hard to perform a socially acceptable identity to audience members, bystanders’ information disclosed could easily cast a negative impact.

4.2 Tensions between Privacy and Interpersonal Boundary with the Audience

Participants expressed their concerns with interpersonal boundary regulation with their audience. Generally, they felt frustrated with unwanted physical and virtual contact, harassment and interruption caused by their accidental information disclosure to the audience. They were also concerned about accidentally disclosing bystanders’ information to the audience, potentially bringing trouble to those bystanders.

Although streamers oftentimes traded their privacy for performance attractiveness, they did set both physical and virtual boundaries between themselves and audience. Physical boundary focuses on the contact in real world whereas virtual boundary denotes the contact in the cyberspace, such as sending friend requests, emails and calls. According to Altman [2], regulating one’s boundaries with others is a critical function of privacy management. Our participants described their concerns with unwanted physical or virtual contact from the audience. Such unwanted contact mostly involved certain identifiable information about the streamers. Such identifiable information would raise significant privacy concerns to streamers, especially the interpersonal boundary turbulence. But the information might not be critical in creating attractive performance to audience. Thus, participants weighed it over attractiveness and set boundaries accordingly. Regulating interpersonal boundaries between the streamers and their audience was challenging because of the real-time nature and openness to the public audience on live streaming. We describe participants concerns with boundary regulation in the next two subsections.

4.2.1 Privacy Concerns about Physical Boundary. Participants described their concerns with undesired physical contact from audiences. Such concern was mostly a result of live streamed disclosure of streamers’ mailing address, school/workplace address, and whereabouts. Disclose of this information was usually not a part of attractive live performance. In many cases, the audience would
randomly ask streamers about their hometown, cities they lived in, and schools. For instance, two participants were asked by the audience to share their mailing addresses with the excuse to mail gifts to the streamers. Most participants chose to decline such questions and restrict such information sharing to protect their own privacy.

In addition, streamers were cautious that audiences could sometimes infer location information from the scenery and landmarks outside the window of the streamer’s room. For example, P13 told us a story he read from the news that a streamer shared the scene outside the window when streaming. As a result, an audience member found the streamer’s place.

Participants also told us that unwanted physical contact could cause a security threat to the streamers and streamers’ families, as well as harassment, i.e., audience sent funeral gifts to troll the streamers (according to P12). What was more bothering was the cost and burden for a streamer to change address. This indicates that streamers were concerned with information exposure that would harm their physical boundary and bring them physical security threats. This concern was mentioned by 10 participants with various lengths of streaming (ranging from 2 months to 3-4 years) and numbers of viewers (ranging from 5+ to 10,000+). For example, P20 (female, 23, student, 2 months, 10,000+) told us:

*My audience offered to order food for me. I declined. It’s (address) private. I stream at home. Some streamers work at the company, so their addresses are mostly the company addresses. But I am concerned. It’s scary. I know I am not that famous. But you know, you have to change your address (if exposed). That’s burdensome."

In this case, P20 was concerned about the privacy of her home address. She did not want the audience to know her exact location in the real world. She also mentioned the unacceptable cost of addressing such a privacy breach, which made her even more careful to restrict this personal information.

### 4.2.2 Privacy Concerns about Virtual Boundary

Unwanted contact happened not only in the physical world but also in cyberspace. Eight participants, who have different streaming experiences ranging from one year to only a few days and different numbers of viewers ranging from thousands to only a few, described their concern about unwanted virtual contact when accidentally sharing contact information during live streaming. Such contact information included the phone number, QQ ID, WeChat ID, in-game ID, and email addresses (WeChat and QQ are two major social media messengers in China). Most participants disclosed their contact information accidentally, such as when they opened a document, a webpage, a push-up notification, or a message, or when they logged in/out of websites and applications during their live stream. As these were normal and frequent operations in daily life, participants found it difficult to avoid them during a live streaming. Once the contact information was exposed, streamers could be contacted and harassed by vicious viewers unexpectedly. For example, P10 (male, 22, student, half year, 300+) told us:

*I once saw such accidents in others’ live streaming. It was a game streamer and he’s kinda famous with around hundreds of thousands of viewers. He was sending some files through QQ and his QQ ID was exposed. Some audience caught that and all of a sudden, his QQ was exploded, like thousands of friend requests flew in. I guessed he had to discard that ID. Another streamer exposed his phone number when he was sharing his phone screen. Again, just in one minute or two, he got tons of calls. And the stream was disrupted, too. So those could happen to me if I am not cautious enough. It would destroy my life."

While unexpectedly disclosing one’s own contact information was annoying, participants worried about accidentally disclosing others’ contact information to the audience, causing them to be unexpectedly disturbed by remote audience members. For example, a streamer might unintentionally
share a friend’s phone number if called by a friend during a live stream if using a mobile phone. As P19 (male, 29, financial analyst, 1 year, 10-20+) said:

_Yea, it happened once to me. I was logging in to my friends’ accounts, two accounts actually (upon my friends’ requests). I thought I stopped sharing the login interface. So I logged in to one account and opened another window to log in to the second one. But when I was done, I found it (screen sharing) was not stopped. I was so scared. Fortunately, it was midnight and no one was there (watching). It would be a disaster if my friends’ accounts got stolen._

When his friends’ account numbers were disclosed, P10 was concerned about a potential threat directed toward his friends. Disclosing contact information to audiences could harassing phone calls, emails, messages, and friend requests, as well as “stream sniping”, a practice of playing a game against a streamer while watching their broadcast to gain an advantage [82]. For example, P7 (26, male, teacher, 3 months, 5+) told us:

_Sometimes when I open my friend list (in the game), they (audiences) could see my friends there and my Battle.net ID. I don’t really want them to see that because if I am playing rank (a play mode in Hearthstone for higher ranking), the audience might want to snipe me in the game based on my ID. It’s like they are trying to join in the same match with me while watching my streams. And they can see my cards._

Such “stream sniping” is not uncommon for streamers. There has been much news about how streamers ran into a set of stream snipers who made trouble to whatever the streamers were playing. Such virtual unwanted contact was also reported in our interviews.

5 STRATEGIES AND CHALLENGES TO MANAGE PRIVACY IN LIVE STREAMING

To address the concerns in the above section, participants reported various coping strategies they adopted to manage their information disclosure. Their strategies can be grouped into two categories: platform-supported strategies and self-developed strategies. However, these strategies were not flawless. Several usability and cognitive problems came in to play when participants applied these strategies.

5.1 Platform-Supported Strategies

We conclude three types of frequently adopted strategies that are supported by the features embedded in DouYu: 1) pause streaming; 2) managing sources of streaming content; 3) adding an overlay. These three features can also be easily found on other live streaming platforms, such as Twitch, YouTube Live and Facebook Live. DouYu has a button on its interface that allows streamers to pause the live streaming. Once activated, the live video will freeze. However, the streamer’s audio is still being broadcasted when this feature is on. DouYu also offers a set of options that allow streamers to freely manage the source(s) of video/audio feeds. Streamers can select whether they want to stream videos of the particular application(s) or entire desktop/phone screen, and audios of the game soundtrack, in-game audio chat, or streamers’ commentary. Lastly, DouYu allows streamers to add overlays to video content. Streamers can add emojis, pictures, and text as overlays to cover a portion/zone in their live videos.

Generally, participants reported that they would use these features when they were concerned that their information disclosure would negatively impact their attractiveness or boundary regulation, such as when checking emails/messages, making payments, and talking about personal matters. Streamers who mentioned these strategies had different lengths of streaming (from 3-4 years to a few days) and numbers of audience members (from 10+ to 10000+). For example, P2 (female, 28, student, 3-4 years, 300+) mentioned:

_I usually broadcast game soundtrack and team chat, because I feel it’s kinda boring if there is just the BGM (background soundtrack in the games). So I stream the team chat about our strategies_
and communications in the game. Sometimes we made little jokes in team chat. Those are fun. But sometimes when we are done the team playing and a few of us left there complaining about some team members, I will pause my stream because you don’t know who’s watching there. What if they spread it to others and to the persons we complain about? So I just pause it and might restart it later.

P2 described two situations where she wanted to configure the source of audio disclosure in her live streaming: 1) when she wanted to improve her task attractiveness, as she believed that disclosing rich audio content could make her live streaming more interesting to audiences; 2) when she wanted to prevent her complaint from being heard by others, which might harm her social attractiveness and boundaries with other players. Managing the audio source was thus effective in these two situations.

5.2 Self-Developed Strategies

While the live streaming platform offers a set of features to support streamers’ management of information disclosure, participants still reported their heavy reliance on self-developed strategies to cope with their privacy concerns. These self-developed strategies include both technical and behavioral strategies.

**Technical strategies** are mostly related to software and hardware outside the live streaming platform. They were adopted by both beginner and experienced participants and by those who had a considerable number of viewers. For example, participants used webcam filters to make their physical appearance look better. They disabled the notifications in settings of the operation systems, signed out of the social applications they used, and removed content they preferred not to share from the desktop and application interface. All these actions were performed on software systems that were independent of the live streaming platform. They assisted the streamers to manage information disclosure and block content from the audience. For example, P12 (male, 18, crew, 3-4 months, 10,000+) told us:

*I logged out every possible social media account and disabled all the notifications and calls on my phone (when streaming) just to leave a good impression on the audience. Also, I had some intimate chats with my girlfriend, and I don’t want them to see that. There was a time, like when I stream for the first time or the second, a call came in when I streamed my gameplay. The entire live video just blacked out, because I only screen shared the game. So when the call came in, the game was interrupted so there was just a black screen to the audience. I was really panic because my company was advertising me for a long while on DouYu and I got like ten thousand viewers watching me there. I just whispered ‘I am streaming’ on the call and hang up. I don’t even remember who was on the call cuz I was freaked out. I lost two to three thousand viewers immediately because they thought my streaming was ended.*

In this case, P12 signed out of social media and disabled the notifications on his phone because he wanted to maintain his task attractiveness assuming that receiving calls during live streaming could drive audiences away. Another motivation for P12 was to protect his and his girlfriend’s privacy. Interestingly, he mentioned that he also used DouYu’s source management feature, indicating that streamers combined different strategies to manage their information disclosure.

Many hardware devices, such as webcams, microphones, and headsets, also offer functions that allow streamers to control their information disclosure, such as the on/off button. Participants noted that they would choose to use such devices during live streaming, as it was quite convenient to control their information disclosure. Three participants reported that they would use double devices (either double computer monitors, or one computer monitor plus one mobile device) to self-censor their physical appearance in live streaming. They would stream on one device and watch on the other device as an audience. Such hardware-related strategies are obviously outside of the live streaming platform. For example, P20 (female, 23, student, 2 months, 10,000+) told us:
Because I use webcam, I had to switch the screen from time to time to check how I looked like, am I too ugly. You know when you play games, you got nervous and looked like an idiot. So I checked my video image from time to time... But when I was really busying fighting in the game, I could forget to check.

Asides from technical strategies, participants also heavily rely on improvised behavioral strategies. Such strategies were dependent on streamers’ mental models of the streaming process. Seven participants mentioned that they would adopt self-related behavioral strategies, such as improving their physical appearance and changing their attitude. These participants had between a few days to 5 years of streaming experience and anywhere from just a few viewers to more than 20,000. For example, P13 (female, 27, full-time streamer, 2months, 10+) explained that she would dress up and wear make-up before her live streaming so as to look beautiful and energetic to the audience. P8 (male, 25, student, 2years, 80+) would also adjust the lighting setup when starting to stream, as a reliable lighting setup made him look professional and enhanced the quality of the webcam feed. Hence, these strategies would address streamers’ concerns regarding their physical attractiveness.

As participants reported the impact of environmental information (i.e., messy bedroom and landmarks outside the streamer’s window) on attractiveness and boundary regulation, they would adopt environment-related strategies to control their background and surroundings. To avoid a busy background undermining their social attractiveness and exposing physical location, participants would use a green screen. The streamers would set up a green curtain as the background and configure the webcam settings to remove everything green; then the streamer would have a transparent background in the video, such as having only the upper body displayed over gameplay. For instance, P16 (male, 20, student, 1 month, 70,000+) told us:

I got a green curtain. It’s like a piece of green cloth. When my background is a mess, my audience might think I am a mess because my personal life is there. So if I happen to have some audience dislike me, they will judge me, like your room is a mess, you gotta be a messy person.

Streamers also adopted audience-related strategies, meaning they would control information disclosed based on the live audience. Generally, participants reported that they would adopt different communication strategies when disclosing personal information to the audience, such as faking information, distracting the audience’s attention, making a joke to switch topics, and simply ignoring/declining the audience’s request for streamers’ personal information. These strategies involved nuancing management of the interpersonal communication with the audience, thus were highly dependent on the streamers’ skills of communication. Participants mostly adopted such communication strategies when their authentic disclosure would negatively impact their attractiveness and boundary. Communication strategies are commonly adopted by participants who have accumulated certain lengths of streaming experience (from 2 months to 5 years) and numbers of viewers (from 80+ to 10,000+). For example, P2 (female, 28, student, 3-4 years, 300+) faked information to hide her social relationships that she did not want to disclose to the audience. However, she also wanted to maintain her attractiveness to the audience. Thus, she used a bit of exaggeration in her communication strategies so that audience would keep their interest in the streamer: “I just made up a little story, you know, exaggerated it or just smiled, made a little joke like ‘Ah, don’t get me started.’”

As participants had mentioned how their bystanders destroyed the information disclose that they had tried to control, they often adopted strategies related to bystanders to prevent disclosure of private information. Similar to audience-related strategies, the strategies with bystanders were also mostly about communication. Six participants including both beginner and experienced streamers described that they would communicate with their bystanders, such as parents, partners, and other family members, in advance about when, where, and why they needed to stream, so as to prevent
bystanders from interrupting the live streaming and undermining the streamers’ attractiveness. For example, P5 (female, 20, full-time streamer, 5 years, 600+) described:

My little brother is only 9 years old. He doesn’t understand streaming is a job. He thinks I’m just playing games. So he shows up every day when I stream, like sitting next to me, eating food there, and coming in and out of my room. The last time I was singing in my stream, and he just came in out of a sudden and sat there, talking to my audience! I told my audience that I ate at 9. He was like ‘no, you ate at 8’. He even shared my birth date and year with my audience. I was shocked. So this year, I talked with him like streaming is a serious job. I raised myself on it. He could only enter my room once per day. And he couldn’t share his name, age, and address in my stream.

In this case, P5’s younger brother was too young to understand the profession of a streamer, thus found it fun to interrupt his older sister, P5’s live streaming. His behavior, including intentionally disclosing P5’s personal information, negatively affected P5’s attractiveness and boundary with the audience. P5 had to explain the significance of live streaming to her younger brother to prevent him from interrupting again.

5.3 Limitations of the Privacy Management Strategies

Although participants adopted various strategies to meet their needs for information disclosure, these strategies were not flawless. We summarized two types of challenges that streamers encountered when deploying privacy management strategies.

5.3.1 Unpredictability, Uncertainty, and Unexpectedness in Privacy Management Strategies. Although streamers actively implement privacy management strategies, there are privacy concerns that cannot be addressed by existing privacy management strategies due to the unpredictability, uncertainty, and unexpectedness in live streaming. Participants reported that while they adopted privacy management strategies to withhold unwanted information disclosure in live streaming, there were times when they could not overcome the privacy challenges through the strategies because they were not able to precisely predict and control the content in the real-time information sharing. Such problem mostly happened in the content of screensharing and audio sharing, such as notifications, calls and automatic webpage redirect, which could not be predicted in advance, but could easily disrupt live streaming, reveal sensitive personal information and cause a negative impact on their attractiveness and boundary regulation. No effective technical features were provided inside or outside live streaming platforms to assist streamers to predict the occurrence of this accidental real-time information disclosure. Thus, streamers were not able to timely implement appropriate strategies to avoid this unwanted information disclosure. For example, P13 (female, 27, full-time streamer, 2 months, 10+) told us:

I was going to buy something in the game. Then it just automatically and unexpectedly connected to my Alipay (a popular payment method in China, similar to PayPal). Boom, all my personal information was exposed. The audience was like ‘OMG, you are so rich!’ I was so embarrassed. I mean I want them to give me gifts. If they see I’m rich, they might not do that (give gifts).

The uncertainty in audience’s reaction is also part of the unpredictability in live streaming. Because audience are anonymous and the live streaming is mostly open to public audience, streamers failed to predict the real-time response from the audience when adopting audience-related privacy management strategies, thus making their strategies ineffective. For instance, participants described how their audience-related strategies, such as faking, distracting, joking, and ignoring, failed when the audience kept asking and trolling the streamers. For example, P12 (male, 18, crew, 3-4 months, 10,000+) said:
I used to find some excuses to distract the audience when I lost in the game, you know, to hide the fact that I am not that skilled. But some audiences just didn’t buy it. They would blame me, like ‘it’s your fault. No excuse!’ posting this directly on the Danmaku.

In addition to the unpredictability and uncertainty in live streaming, technical strategies that are supported by emerging technologies, such as source management and webcam filter, might fail to work as expected when streamers use them, thus negatively impacting the streamer’s attractiveness and boundary. Participants mentioned a set of emerging technical features that need to be further improved. For example, the source management feature should display a message to the audience if the selected sources (preferred information disclosure) crashed during the live streaming. The webcam filter may cause an unbalanced skin tone and face shape. For example, P20 (female, 23, student, 2 months, 10,000+) said: “Those beauty filters allow you to adjust the shape of your face or your eyes. But if there’s something in front of your face, or if you move in or out of the filters, your face becomes weird, like being squashed.”

5.3.2 Cognitive Burdens Brought by the Privacy Management Strategies. Even if the privacy management strategies work effectively, deploying these strategies brings extra cognitive burdens to streamers. Self-developed strategies often added significant cognitive burdens to streamers because these strategies were not supported by the live streaming platform. Participants had to refer to software, hardware and behavior outside the live streaming platform to deploy their strategies, which cost them much effort. This was even more burdensome during live streaming because streamers were mostly performing multiple tasks at the same time, such as keeping up their competent performance and interacting with the audience. Thus, participants reported that using self-developed strategies caused too much cognitive burden on them. For example, P9 (female, 20, student, 3 years, 20,000+) told us that she needed to wear makeup, contact glasses, and fake eyelashes while streaming games, which made it hard for her to concentrate and it impacted her performance. P5 (female, 20, full-time streamer, 5 years, 600+) complained that she had to check the content of screensharing several times every time before she streamed in case inappropriate content was broadcast, such as WeChat and QQ messages.

Participants also complained about the cognitive burden that they had to continuously remind themselves to implement privacy management strategies during live streaming. This is because some information disclosure that is inappropriate in live streaming is actually common and appropriate in the offline setting, such as sending intimate messages to social relationships and checking emails. Thus, streamers might sometimes fail to realize that the context of information sharing had changed during live streaming. They might disclose unwanted information without moderating. For example, P15 (male, 23, student, 3 months, 1000+) said:

I used to delete my chat history before streaming. But I could forget it. It’s not something that you have to always keep in mind. Once I was chatting with my girlfriend about what she was doing last night. I forgot to delete it and my audience saw that. They were making fun of it like ‘stop PDA (Public Display of Affection).’ I don’t like it because I am supposed to be a gaming streamer, not a romantic streamer. The content here should only be about games.

6 DISCUSSION

In this paper, we investigated streamers’ privacy concerns, strategies and challenges regarding their information disclosure during live streaming. Through an in-depth interview study with 20 streamers, we found how streamers defined their privacy concerns in live streaming, the rationale and dynamics behind their privacy attitudes and practices, and the challenges in managing privacy in live streaming. Our findings showed that while streamers were generally concerned with the exposure of their personal information and the interruptions to their privacy boundaries with the
audience, certain information disclosure would greatly improve the attractiveness of their live performance and increase their financial revenues from live streaming. Thus, their privacy concerns interplayed with their desire to maintain physical, task and social attractiveness in live streaming, making it challenging for them to manage their information disclosure. To cope with their privacy concerns, streamers relied on both platform-supported and self-developed privacy management strategies, such as selective disclosure, hardware control and communicative strategies. While these strategies cast specific outcomes on mitigating streamers’ privacy concerns, some of them had usability issues and introduced cognitive burdens, thus needing to be further improved in the future. We discuss the implications and contributions of these findings in the next few subsections.

6.1 Privacy Management in Performance-Centric Information Disclosure

Our findings reveal the intertwined relationships between streamers’ performance creation, revenue seeking, and privacy protection in live streaming. Prior privacy research mostly examined users’ privacy concerns and strategies on social media, such as Facebook and Instagram, which are designed for online social networking, rather than for performance creation and revenue seeking. These social media platforms have been mostly used for keeping in touch with others [68], maintaining relationships [22], and reinforcing social interactions [45]. Thus, privacy concerns on these platforms are mostly about how exposure of personal information [27] and the collapse of different types of social contexts [62] disrupt their desired online self-presentation, online social interactions and social relationships with different online social networks [1, 6, 44, 83].

Unlike the socialization-centric social media platforms, live streaming is for users to share an attractive performance with a vast public audience, rather than to maintain social networks. One primary motive behind sharing an attractive performance is to make financial revenues through gifting from the audience [47]. Thus, streamers’ privacy concern is not only about exposure of personal information, but also intertwined with whether information sharing in live streaming enhances or undermines streamers’ performance and attractiveness to public audience, which ultimately impacts their financial revenue.

This socioeconomic aspect is rare in privacy issues on socialization-centric social media. It indicates that the personal information that is appropriate or inappropriate to share is differently defined between live streaming and traditional socialization-centric social media. Certain personal information, such as physical-appearance-based information, which is usually shared through photos and generally considered to be private and to cause various privacy risks on socialization-centric social media [1, 70], can make streamers’ performance attractive to public audience. Thus, it is a must-share for many streamers in live streaming because of its essentiality in building a personal and attractive performance. Several interviewees, such as P2 and P5, mentioned that they chose to be on camera to attract an audience, although they had deep concerns that exposing real physical appearance in live streaming might reveal their identifiable information. Meanwhile, some personal information that is deemed appropriate to be shared on socialization-centric social media, such as romantic relationships [4, 91] and emotional expression [17, 41], might no longer be beneficial to be shared in live streaming because, based on our interview findings, such information might hurt a streamers’ performance and attractiveness. For instance, P20 tried to hide her relationship status in live streaming because it would reduce the audience’s interest in watching her streams. Therefore, the performance-centric and the socioeconomic aspects are deeply intertwined with the privacy issues for streamers and fundamentally influence streamers’ privacy behaviors. The importance of performance creation and revenue seeking should be leveraged when we evaluate the information sharing practice and privacy concerns in the context of live streaming.

Moreover, the dynamics between streamers’ performance creation, revenue seeking, and privacy protection entails that privacy management strategies that are effective on socialization-centric
social media will not necessarily function on live streaming. For example, blocking unwanted contacts and withdrawing unwanted information, which are commonly used on socialization-centric social media [94], will not work on live streaming because they reduce streamers’ attractiveness, push the audience away, discourage audience to gift, and ultimately undermine streamers’ revenue. As shown in our interview findings, participants reported heavy reliance on strategies that could both decorate their performance and preserve their privacy, such as removing unwanted content, using beauty filters, and lying, as these strategies would not offend the audience and could potentially increase their income. This indicates that the privacy management strategies that commonly exist on traditional socialization-centric social media might not be sufficient for streamers to protect their privacy in live streaming. The performance-centric and the socioeconomic aspects should be paid attention to when we design the privacy support on live streaming.

This important role of performance creation and revenue seeking in streamers’ privacy concerns and strategies emerged from our interviews and resonates with prior work asserting streamers’ performance is a central element in live streaming and performance is driven by monetary incentives. For example, Li et al.’s work showed how streamers prepare and perform strategic, supplementary, and causal information presentation to create attractive performance [48]. Fietkiewicz et al.’s work elaborated how streamers chose topics for their performance by evaluating the possibility to make a living from it [24]. Woodcock and Johnson’s work also reported the affective labor interwoven in the activity of live streaming, namely how streamers create content, prepare their mood, control their stress, respond to an audience in a socially active way, and perform the identities that are accepted by the audience [99]. These studies demonstrated the pervading performance-driven and socioeconomic nature in the live streaming culture, which in our study is also deeply rooted in streamers’ privacy concerns and strategies. We suggest future work should incorporate such socioeconomic consideration when examining streamers’ attitudes and behaviors in the context of live streaming.

6.2 Heightened Privacy Challenges in Compliance with Contextual Norms

Our study uncovered the heightened privacy challenges to boundary regulation due to the real-time nature of live streaming. Prior work has touched upon how the privacy issues are worsened on live streaming. Li et al.’s work showed that managing the disclosure of numerous pieces of information (i.e., audio and video disclosure) at the same time while simultaneously performing (i.e., playing games and chatting with teams) induced a significant cognitive load on users in the streams [50]. However, this prior work has only examined the bystanders’ privacy issues, namely the people being streamed by the streamers. Streamers’ privacy issues have been left unexplored. Our present study filled this gap by focusing on the role of streamers in live streaming privacy challenges and furthermore highlighted the severeness of the physical/virtual boundary issues in the use of synchronous social media.

In offline communication, people’s boundary regulation is governed by context-specific information norms [66]. Information sharing that is appropriate in one context may become inappropriate in another context [66]. For example, when people see the social relationship, they are speaking to changes from close to weak ties, certain information disclosure, such as intimate details and family matters, might disrupt the interpersonal boundary. In this case, people can actively accommodate their disclosure to the changing context because the cue of context change is visible to them.

When it comes to asynchronous social media, due to the absence of knowledge about the context change, users can only imagine the online audience with whom they are interacting with [62]. The imagined audience can be entirely different from the actual readers of the disclosed information [62]. Thus, many researchers have proposed solutions to address the issue of imagined audience for users to easily regulate their privacy boundaries, such as presenting users the view that a particular
audience has of their disclosed information [51] and informing users about the potential audience to their information disclosure [89].

However, these solutions assume that users have sufficient time to check whether their information disclosure complies with the current context and whether they have a chance to change their information disclosure before sharing, which are unlikely on synchronous social media. First, streamers have little time to think about the change of context, the change of information norms, and the compliance between their information disclosure and the norms, thus are unable to accommodate their disclosure accordingly. For example, several participants (i.e., P10, P19 and P7) shared their experiences where they were conducting common daily operations (i.e., logging into an account, checking friends’ status, and browsing emails/messages), but failed to realize the change in the context (from daily private life to live streaming) and the mismatch between their information disclosure and the information norms on live streaming.

Second, even when streamers are able to detect the context change, they have little time to generate an accurate estimation of the audience they are interacting with. This is because most live streaming channels are open to anonymous public viewers, meaning anyone can join at any time during the streams. When streamers have many anonymous viewers, it is difficult to precisely gauge who is watching. For instance, P2 was concerned that her streams might be viewed by the subjects she mentioned in her streams. P18 was worried that her real-world social relationships might accidentally join her streams and view her unwanted content. Therefore, compared to asynchronous social media, the real-time nature of synchronous social media, such as live streaming, makes it more challenging for users to achieve contextual integrity and desired boundary regulation. It could potentially cause more severe privacy risks, such as disclosing account credentials and exposing identifiable information. We suggest any future work pay attention to privacy challenges, contextual integrity, and boundary regulation caused by real-time information sharing. More research is needed to address the privacy issues in the real-time setting, since live information sharing has become increasingly popular in recent years.

6.3 Discrimination against Female Streamers in Live Streaming

Our paper also contributed to the understanding of discrimination against female streamers in live streaming. Prior work has shown that female streamers are generally considered to be a marginalized and vulnerable user group in the live streaming community, since they face two major challenges in their live streaming performance: 1) the misogynist attitudes that place women’s bodies in opposition to the gaming culture and neglect women’s embodied presence [72]; 2) the objectification that equates a woman’s worth with her body’s appearance [65]. Our findings support these prior studies, as we also witness an evident theme about the gender-based discrimination and harassment that disturbed female streamers’ information sharing.

What we add to the prior work is that our findings shed light on the gender issues in live streaming from the perspective of privacy management – namely how the gender issues impede female streamers’ information sharing and privacy management. Our study revealed that the tension between privacy and attractiveness is a factor that makes it difficult for female streamers to cope with the gender-based discrimination in live streaming. Prior work has shown that female streamers suffer from sexual harassment (i.e., sexual comments and solicitation, etc.), hate speech, doxing, and appearance attack during live streaming [72, 88]. Uttarapong et al.’s work found that some viewers identified and harassed the female streamer offline based on the personal information shared by the female streamer in streams [88]. Thus, the female streamers would keep personal details minimal and avoid face cam on stream [88]. However, our study shows that it is not that simple. Withholding personal details and physical features would hurt streamers’ attractiveness. Female streamers, especially novice female streamers, need attractiveness to jumpstart their live
streaming career. They can be easily persuaded to trade privacy for attractiveness, making them more vulnerable to the long-term privacy risks which they might not be able to foresee in the moment of live streaming, such as misuse of their physical features, stalking and harassment. For instance, P2 shared how effective it was to attract an audience when female streamers chose to disclose their looks in their streams. P17 also mentioned how disclosing physical features more positively influenced attractiveness for female streamers than for male streamers. From the perspective of privacy decision-making, users weigh gains and cost in information disclosure, which is referred to as privacy calculus [18]. If users evaluate that the disclosure brings them more benefits than costs, they are highly likely to make the disclosure. In the context of live streaming, the difficulties in making rational privacy calculus under the broader discriminatory climate in live streaming is much more for female than male streamers. The immediate benefits of displaying physical features on live streaming are unfairly amplified for female streamers. They are likely to overestimate the immediate gain from disclosing physical features and underestimate the value of their privacy. Thus, to facilitate female streamers to cope with the gender-based discrimination in live streaming, both privacy protection and attractiveness management should be considered in future research.

Second, even when female streamers value their privacy, the gender-biased discrimination on live streaming weakens female streamers’ right to disclose or withdraw their personal information as they wish. The penalty from the withdrawal of personal information is much more significant for female streamers than for male streamers, making it difficult for female streamers to decline unwanted information sharing, such as physical appearance and age. For instance, despite of her concern about sharing looks, P5 had suffered from low attractiveness and low revenues when she declined to be on camera. On the contrary, most male interviewees did not report such significant loss of attractiveness when they chose to be off camera. The unequal penalty from the withdrawal of personal information hurts female streamers’ right to be private and disturbs their desired privacy boundaries with audience.

Additionally, the ageism, lookism and discrimination against women with a partner that pervades the live streaming culture limits the ways for female streamers to freely present themselves. Many participants mentioned in the interviews that the audience commonly expected female streamers to be young, good-looking and single (P5, P20 and so on) and would gift such female streamers more often. If female streamers were not so, the audience would exhibit a discriminatory attitude, such as joking about streamers’ partners, calling streamers “aunt” and making fun of the streamers’ looks. Such toxic expectation and attitude deny female streamers’ right to freely self-disclose without being subject to insult or discrimination, dictate the stereotype that female streamers can only present themselves in certain ways, and eventually impede their construction of desired self-identities. Female streamers thus need to invest more effort than male streamers in order to manage their audience expectation.

Our work unpacks the severe gender issues in live streaming from the perspective of privacy management. Together with prior work that investigates the gender-based discrimination and harassment in live streaming from other perspectives [72, 87, 88], it is obvious that gender issues have become a common problem that affects the diversity and freedom in the live streaming community. As live streaming has become a popular platform for people to present novel and interesting performance, we call for more research and attention to the gender-based discriminatory climate in live within the culture.

7 DESIGN IMPLICATIONS

Building upon our discussions of the privacy concerns and strategies that the streamers have, we offer several design implications for live streaming platforms. To address the tension between

creating attractive performance and preserving privacy, live streaming tools should incorporate more features that can assist streamers to make informed decisions on information sharing. Based on our findings, the design of these features needs to consider streamers’ privacy needs and desire to generate attractive content in live streaming. First, to avoid streamers irrationally overestimating the benefits of disclosing personal information and underestimating the privacy risks in the long run, the live streaming tools should provide sufficient information to raise streamers’ awareness of the privacy risks associated with their information disclosure. In our interviews, it was common that streamers, especially female streamers, were well aware of the attractiveness obtained from information sharing and underestimated the associated long-term privacy risk, such as being identified offline. To raise streamers’ awareness of the long-term privacy risks, an effective approach is to provide streamers with online interactive tutorials that introduce possible privacy consequences resulting from overexposure of personal information in live streaming and coping strategies. The tutorials can be displayed on the first-time streamers live broadcast and periodically. Another example is to highlight true stories about privacy breaches that have happened to other streamers in the news feed. A few participants, such as P10 and P11, mentioned that the true stories they encountered online alerted them about the privacy risks from live streaming, warned them to be more careful about their personal information, and thus helped them make better privacy decisions. Thus, incorporating and highlighting such information can effectively improve streamers’ privacy awareness.

Second, live streaming tools should provide features for streamers to hide unwanted information disclosure but not hurt their attractiveness. Current features that are commonly used by streamers to hide unwanted information disclosure include webcam filters and overlays. The former can be used to hide streamers’ physical features and the latter can be used to hide screensharing content. However, these features do not consider streamers’ desire to maintain attractiveness and retain audience members because they disrupt the streamers’ performance (mentioned by P20) and make it obvious that streamers want to keep something secret from the audience (mentioned by P2). Therefore, live streaming tools should offer features that take both attractiveness and privacy into account. For example, webcam filters and overlays can be more intelligent and adaptive so that they can be automatically and naturally accommodated to the streamed performance. Live streaming tools should provide features for streamers to better understand an audience’s need and evaluate the effect of their privacy management strategies so that streamers can develop diverse approaches to attract audience members, instead of having to disclose unwanted personal information. Examples can be embedded surveys and interviews in the live streams. Such features can also give streamers more information and time to better decide the trade-off between performance creation and privacy protection.

Intelligent notification features and mechanisms that can assist streamers to notice the real-time change of information sharing context should be offered in live streaming tools. Notification of change of context is not new. Many live streaming tools already provide notifications when new audience members join in or when a recording is started. However, such notifications are not sufficient because, based on our interview findings, many changes of context, such as a pop-up login page, calls from real-world connections, push messages, in-game communications, and bystanders’ interruptions, are not included in notifications from the live streaming tools. Streamers have to perform extra tasks, such as disabling notifications in the device settings, adjusting the audio/video sources and adding overlays, to address different changes of context. However, these extra tasks indiscriminately block information under all the contexts and require much labor from the streamers. We thus suggest the notification of change of context be more integrated, intelligent, and granular. First, the notification of change of context should be configured in live streaming platforms
and integrated with other software in the live broadcast (i.e., games, audio chat, web browser, etc.). Streamers can perform the configurations of notifications in one place without having to adjust settings in other software. Second, the notification of change of context should be more intelligent, adaptive and predictive. For example, the notification should be able to detect an incoming pop-up login page, calls from real-world connections, push messages, in-game communications, and bystanders’ interruptions during live streaming, and predict the appropriateness based on the current audience in the live stream. Thus, streamers can decide whether to share information under the changed context before being streamed. This might require context-awareness and intelligent techniques to support the implementation of the notifications. Lastly, the notification content should be granular so that the streamers can have more information about the change of context to make informed privacy decisions. For instance, different colors can be used to show the appropriate levels of the change of context. A summary of the change of context and the information about the current audience should be included in the notifications. Streamers can customize the notification content and format to help them be aware of the change of context.

Lastly, to address gender issues in the privacy management in live streaming, moderations to the discriminatory attitudes and behaviors that make female streamers vulnerable to privacy risks should be given sufficient attention in the design of live streaming tools. There has been increased discussion on developing moderation practices in the live streaming community [9, 10, 96]. Many live streaming platforms have well-trained employees to handle inappropriate broadcasting content. Streamers either moderate the audience’s comments on their own or hire volunteer moderators [75, 76, 96]. There also exist automatic moderation tools that use algorithms to filter abusive messages. However, most of these moderation mechanisms focus on harassment, trolls, and hate speech in live streaming. Few of them focus on privacy issues or are specific to the gender-based discrimination. Thus, moderation mechanisms that are designed for the privacy and gender issues in live streaming are needed. We suggest more moderators from marginalized populations and moderators who have knowledge about privacy management should be included in the moderator community in live streaming, as they may understand female streamers and other marginalized streamers’ struggles and privacy challenges better. Previous work points out that users generally preferred friends to be moderators compared to paid or volunteer strangers to protect personal information [60]. However, turning for help to friends may not work for female streamers in live streaming because it might break the interpersonal boundary. P18, for example, did not want her friends to be aware of her broadcasting. Therefore, female streamers may choose loyal female audience or peer female streamers to be their moderators who have long-term interaction with the streamers and understand their gender-specific concerns and needs. Additionally, as Zolides has studied how the community guidelines and policies structurally encourage forms of gendered domination by reinforcing hegemonic and disempowering norms of femininity in an already highly masculine space [104], we call for more policy research and design to address the harmful understandings of gender influenced by the content moderation policies and community guidelines.

8 LIMITATIONS AND FUTURE WORK
Our study has several limitations. First, all the participants are Chinese DouYu streamers. As such, our results may not be generalized to users from other countries or cultural backgrounds. Prior research on cross-cultural studies has shown that people’s privacy concerns and strategies toward information disclosure on social media could be distinct from culture to culture [3, 38]. Given that all our participants are Chinese, their privacy concerns and strategies in live streaming might be influenced by the Chinese culture. For instance, due to the salient importance of social relationships and social identities in the Chinese culture, information sharing that is socially unacceptable might particularly concern the Chinese streamers. However, such post hoc speculations based on the prior
literature need to be further examined in future studies with specific culture-related probes. The primary goal of the present study is to explore streamers’ privacy concerns and strategies on a novel social media platform. Hence, we didn’t include cultural related questions in the interviews. Future work is suggested to investigate the role of cultural factors in streamers’ information disclosure management.

Second, the majority of our participants (17 out of 20) stream about games, with a few exceptions who stream about singing, dancing, and so on (3 out of 20). This is because DouYu is a leading game-centric live streaming platform in China [20] and gameplay streaming is a popular live streaming scenario which is also the case for other platforms [64]. However, it is possible that streamers who stream other topics, such as travel experience, shopping, and cooking, may have different privacy attitudes and behaviors. Hence, we suggest future work explore streamers’ privacy management who stream topics other than what we have covered in this paper.

Third, although we recruited through diverse channels, our participants are mostly well-educated. This might be because more than 65% streamers on DouYu have a college educational background [33]. Streamers who are less educated may have different privacy concerns from the well-educated streamers. Therefore, our sample may not well represent streamers with different education backgrounds. We suggest future work explore the privacy concerns and strategies of streamers with diverse educational backgrounds.

Fourth, although we considered full-time/part-time, length of streaming experience and number of viewers when recruiting streamers, we failed to interview more full-time streamers and streamers who were famous, had hundreds of thousands of viewers, and developed their streaming into a successful career. This is because most famous streamers usually have contracts with DouYu or other agencies, which pose restrictions on streamers being interviewed. These streamers may encounter different privacy issues and adopt different strategies to manage their information disclosure. Therefore, we suggest future work develop better strategies to recruit such streamers. We also suggest large-scale quantitative studies examine whether professionalism, length of streaming experience and number of viewers would significantly influence streamers’ privacy attitudes and behaviors.

9 CONCLUSION
In this paper, we presented an investigation of streamers’ privacy concerns and strategies in live streaming through an interview study with 20 streamers. We found that streamers were concerned with the information disclosure that would harm their attractiveness to the audience and disturb their interpersonal boundary with the audience. To cope with their privacy concerns, streamers relied on both platform-supported and self-developed privacy management strategies, such as selective disclosure, hardware control and communicative strategies. While these strategies cast a certain effect on mitigating streamers’ privacy concerns, some of them had usability problems and required too much cognitive effort, thus needing to be further improved in the future. We discuss empirical contributions and design implications of our findings.

REFERENCES


I Am Concerned, But…‘: Streamers’ Privacy Concerns and Strategies In Live Streaming Information Disclosure

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## 10 APPENDIX

### Interview Questions

**Streaming Experience:**
- What’s your gender?
- What’s your age?
- What’s your occupation?
- How did you know DouYu?
- How long have you been streamed on DouYu?
- Why did you choose to stream on DouYu?

**Streaming Content:**
- What topic(s) did you broadcast on DouYu? Why did you choose such topic(s)?
  - When you broadcast the topic(s), what information would you like to share?
  - Could you please describe that in detail with an example?
  - Why did you want to share such information?
  - Who were the audience?
  - How did the audience react to your information sharing?
  - Did you have any concerns when you shared such information?
  - If yes, what concern? Why did you have such concern?
  - What happened after you shared the information?
  - What information did you prefer not to share with your audience?
  - What strategies did you adopt to prevent unwanted information sharing?

Have you ever shared any information that you didn’t want to share with your audience?
- What happened at that time? What information did you share?
- Why did you think such information sharing was unwanted?
- What did you do when the incident happened? How did the audience react?
- Did the incident affect your life?
- Did you have any regrets on it?

**Streaming Equipment:**
- What equipment do you use during live streaming? (e.g., webcam, mic, etc.)
- How did you use it?
- Why did you use such equipment?
- When you used such equipment, what information could the audience get?
- What information sharing was acceptable to you? What not? Why?
- How did you prevent unwanted information sharing?
- If you didn’t want to use certain equipment, why not use this equipment?
- How did you disable such equipment?

**Viewers:**
- How many viewers did you have?
- Who were your viewers?
- Did the viewers have an impact on your streaming? How?
- How did the viewers react to your streaming?
- When you interacted with the viewers, have you ever accidentally shared personal information?
- Have your viewers ever asked you any unwanted questions or made any inappropriate request to solicit your personal information?
- What questions/requests?
How did you respond at that time?

Usage of Privacy Setting:
- What features did you often use on DouYu? What do you think of them?
- Were there any settings on DouYu that protect streamers’ personal information?
- Which one did you use?
- How did you know these settings?
- How did you set up the settings?
- How did you like the settings? Any problems to use them?
- What improvement do you suggest for the settings? Why? How?

Besides what you have told us, do you have any other concerns during live streaming?
Have you ever heard any streamers who accidentally shared unwanted personal information in live streaming? If yes, what happened? Any consequences? What did you do after hearing such news?

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