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Xiaofei Song
University of Nottingham Ningbo China, xiaofei.song@nottingham.edu.cn

Mengyao Fu
City University of Hong Kong, mengyaofu3-c@my.cityu.edu.hk

Jie Fang
University of Nottingham Ningbo China, jie.fang@nottingham.edu.cn

Zhao Cai
University of Nottingham Ningbo China, zhao.cai@nottingham.edu.cn

Alain Chong
University of Nottingham, alain.chong@nottingham.edu.cn

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Completed Research Paper

Xiaofei Song
University of Nottingham Ningbo China
Ningbo, China
xiaofei.song@nottingham.edu.cn

Mengyao Fu
City University of Hong Kong
Hong Kong, China
mengyaofu3-c@my.cityu.edu.hk

Jie Fang
University of Nottingham Ningbo China
Ningbo, China
jie.fang@nottingham.edu.cn

Zhao Cai
University of Nottingham Ningbo China
Ningbo, China
zhao.cai@nottingham.edu.cn

Alain Chong
University of Nottingham Ningbo China
Ningbo, China
alain.chong@nottingham.edu.cn

Abstract

Live streaming platforms are promoting a novel format of entertainment called PK event where live streamers compete to solicit virtual gifts from viewers. Although the two live streamers in a PK event come across as rivals, they implicitly collaborate to emotionally arouse viewers and solicit virtual gifts. We advance a curvilinear moderated mediation model to disentangle the effects of streamers' shared PK experience on revenue growth through enticing viewers' emotional arousal, which is moderated by streamers' within-team experience acquisition difference. Estimating a multilevel linear model on a sample of 118,323 PK records, we discovered that shared PK experience has an inverted-U-shape relationship with emotional arousal level, which is positively associated with revenue growth. We further attested to the moderating influence of experience acquisition difference in strengthening this curvilinear relationship. Our findings help platforms to improve team member recommendation systems and streamers to find the "right" teammates for optimizing PK performance.

Keywords: Live streaming, PK, shared experience, emotion, variety-specialization balance.

Introduction

Entertainment Live Streaming (ELS) platforms (e.g., Douyu, Huya, and Twitch.tv) have given birth to a vibrant live streaming industry that offers a novel form of entertainment with computer-mediated real-time interactions. Live streamers (hereafter "streamers") recruited by ELS platforms or agency firms (i.e., streamer guilds) broadcast live content, including gameplay, interactive chats, and talent show. Viewers could comment on streamers and reward their favored ones by sending virtual gifts purchased with digital currency or tipping. ELS platforms and streamers would then split the gifting/tipping revenue. Rooting in such a monetization approach, arousal of viewers' emotions has drawn growing attention to investigate factors contributing to viewers' gifting/tipping (e.g., Lee et al., 2018; Zhang et al., 2019). *Emotional arousal* refers to the extent to which an individual's emotion is intensified (Yin et al., 2017). Current live streaming studies highlighted emotion arousal as an intermediate that bridge each independent streamer and the

purchase behavior of a viewer (e.g., Zhou et al., 2019). The common assumption is that the streamer-viewer interaction is a "one-to-many" process. Originating from YY Live in China, ELS platforms facilitated a "many-to-many" variation for emotional arousal termed PK (Zhang et al., 2019). PK refers to a short-period task proactively initiated by two or more streamers, where they co-broadcast and compete for higher gifting/tipping revenue through showcasing talent (e.g., dancing and singing) (Lee et al., 2018; Zhang et al., 2019). With growing popularity, PK offers a promising research context for comprehending emotional arousal as a team task. A successful PK task demands streamers cultivate a feverish ambiance (Lee et al. 2018) and ignite viewers' emotions to boost their revenue (Lin et al., 2021; Zhou et al., 2019). In a bid to monetize collaborative PK performance, the platform tends to recommend suitable streamers while teaming a PK team. For instance, Douyu and Tiktok provide a list of potential teammates with similar characteristics (e.g., follower number and past PK times), while Tiktok specifically recommends selecting from streamers' friend lists. It posits the challenge for the platform of guiding the "right" team member(s) recruitment for a promising PK success.

The platform encourages streamers to select team members among their acquaintances, for an experienced team may deliver a smoother collaboration and a better performance (Reagans et al., 2005). It has given rise to a novel form of task repetition in the ELS environment. With shared PK experience accumulated through previous PK collaboration, streamers could learn about their combined strengths and shortcomings when collaborating (Honoré, 2020; Reagans et al., 2005; Shah et al., 2019). Therefore, they could build up familiarity with each other through PK task repetition (Akgün et al., 2015; Huckman et al., 2008). Such familiarity could contribute to the ease of communication (Honoré, 2020) and thus better team outcomes (Taylor and Greve, 2006). But at the same time, the entertainment industry relies on content freshness to attract and retain viewers for monetization (Chae et al., 2018; Yaveroglu and Donthu, 2008). The appeal of a fixed PK team may decline over time due to a loss of content freshness in the eyes of viewers (Chae et al., 2018; Du, 2014). Considering the countervailing effects of familiarity and freshness, this study aims to elucidate how streamers' shared PK experience affects viewers' emotional arousal in a non-linear pattern and then affects revenue.

Apart from shared experience among team members, prior research also attested to individual differences in experience's effects on team member recommendation(e.g., Haas, 2010; Honoré, 2020). Experience accumulation is vital for streamers to arouse viewers' emotions, for skills and trends are dynamic and ever-changing across content categories. Individual learning of a streamer could face a tradeoff between variety and specialization. Specialization highlights the depth of exposure to a focused task, while variety captures the breath of task experience (Narayanan et al., 2009). Considering that ELS categories tend to develop different routines for completing PK (e.g., dance contests in the talent show category and quizzes in the chatting category). A streamer could spend most of his/her time absorbing representative tacit from specialization and smoother same-category collaboration in PK; otherwise, diverse PK techniques and easier adoption to cross-category communications from variety (Fahrenkopf et al., 2020; Fong Boh et al., 2007). Contextualized to PK teams, we define *experience acquisition difference* as the disparity in team members' relative exposures to specialization versus variety. A higher *experience acquisition difference* could indicate a border disparity in individuals' skill toolkits. Studies have demonstrated that such disparity may lead to serendipity with novel ideas generated via extending each other's knowledge boundaries (Tiwana and McLean, 2005). Building on that, freshness remains high even when a PK team has an abundant shared experience. This study endeavors to uncover the moderating role of experience acquisition difference played in the relationship between shared PK experience and emotional arousal.

We analyzed data collected from a leading ELS platform in China to disentangle the effects of shared PK experience and experience acquisition differences in determining emotional arousal and revenue growth. Our dataset contains 118,323 PK records from October 1st, 2019 to December 31st, 2019. By validating our hypothesized relationships, we contribute to the extant literature on three fronts. First, we investigate the collaboration between streamers in delivering PK events, an area that remains underexplored in prior research on live streaming. While extant literature has shed light on the relationship between streamer-viewer interactions and viewers' activities (Lee et al., 2018; Lin et al., 2021; Wohn et al., 2018), we scrutinize the role of streamers' shared PK experience played in enticing viewers' emotional arousal. Second, we enrich the ongoing scholarly discourse on enhancing viewers' emotional arousal to attract virtual gifts (Lin et al., 2021; Zhou et al., 2019). Building on the countervailing effects posed by familiarity and freshness, this study illustrates how streamers' shared PK experience impacts viewers' emotional arousal in a curvilinear fashion. We also unravel how viewers' emotional arousal brings about revenue growth to streamers, quantifying the

monetizing value of PK events compared to regular live streaming events. Third, by scrutinizing the moderating influence of experience acquisition difference on the relationship between streamers' shared PK experience and viewers' emotional arousal, we extend previous work on the impact of shared experience on task outcome from conventional on-site workplace to the context of online teamwork (Haas 2010; Honoré 2020).

Theoretical Background

PK as a Unique Entertainment Live Streaming Task

ELS is featured live content, computer-mediated interaction (Hilvert-Bruce et al., 2018; Hu et al., 2017), and pay-what-you-want (Lin et al., 2021; Lu et al., 2021), compared with traditional entertainment services. Specifically, the content delivered by ELS is in real-time. There are two major types of ELS content: game-playing streaming and the talent show (Lee et al., 2019; Sjöblom and Hamari, 2017). ELS allows streamers and viewers to interact in digital-enabled live streaming rooms, regardless of the geographic distance. The live presence of the streamer's voice and image could motivate viewers to communicate with the streamer by sending comments (E. Yu et al., 2018). Meanwhile, viewers can also use the chat box to send textual messages (Zhou et al., 2019). For the monetization model, ELS adopts the pay-what-you-want business model (Lin et al., 2021). Viewers could follow, comment, and view live streaming content without paying. They are encouraged to send a monetary reward to streamers through virtual gifts. These virtual gifts are bought online and act as a monetization medium. Viewers use it to support favored streamers, while streamers and platforms split the revenue gained from the monetary value of the virtual gift.

Figure 1. A Typical PK Process
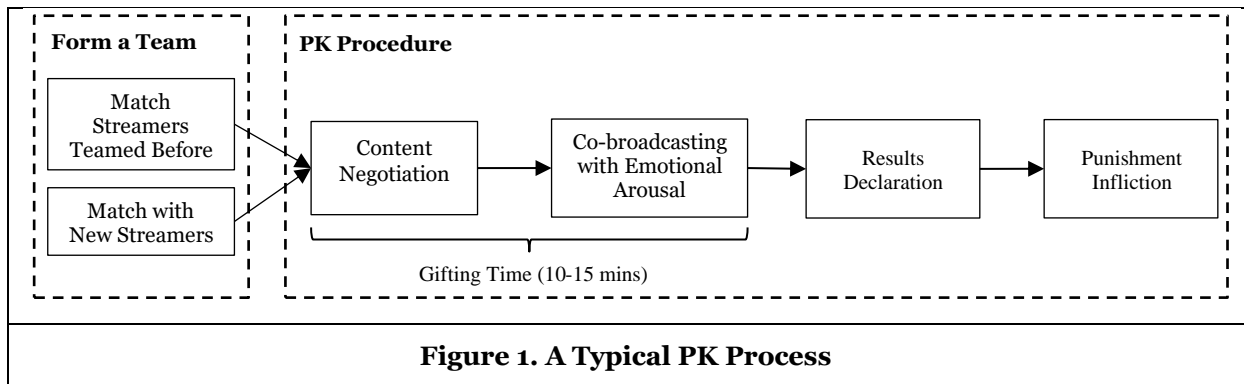
PK is a unique ELS event whereby streamers team up to compete to solicit virtual gifts given a limited time. It resembles a World Wrestling Entertainment (WWE) wrestling show where athletes collaborate to perform a scripted contest to entertain viewers. As shown in Figure 1, a PK streamer team collaboratively negotiates, broadcasts, and acts (e.g., same dancing move or quiz in turn) for a higher score. The winner could decide a punishment for the loser (e.g., meme performance and funny facial painting). Beneath the streamer competition, PK entails a live streaming task for streamers that aims to bolster virtual gifting behaviors during a short period. In summary, they utilize PK to solicit virtual gifts by persuading viewers that they could help their favored streamer win (Zhou et al., 2019). Independent streamers team up for completing the PK task, which suggests that a PK team is a task-based team that requires related skills (e.g., talent show contest skills) (e.g., Gibbs et al., 2017; Staats and Gino, 2012). In such a way, streamers involved in PK may expect to earn more than ordinary live streaming within equal time. Utilizing PK for benefiting monetization, ELS platforms attempt to provide team member recommendations when streamers initiate a PK event, for example, Tiktok displays a list of team candidates with similar followers, popularity, and past PK times. However, matching similar streamers might not always lead to a better team outcome, as repeated team appearances may bored viewers (Chae et al., 2018). This study aims to better understand the mechanism behind PK from the perspective of emotional arousal with task repetition.

Emotional Arousal in PK

PK highlights the importance of emotional arousal induced by the competition task. Existing literature has pinpointed that entertainment activity can evoke emotional arousal (Cronin and Cocker, 2018; Y. Yu and Wang, 2015). As attested in prior studies, when a focused group of individuals (e.g., sports fan groups) gather together, a shared mood such as hostility and happiness could rapidly intensify (Durkheim and Swain, 2008). For instance, an empirical study on tweet sentiments during five 2014 Federation Internationale de Football Association (FIFA) World Cup found that the audience's emotions were aroused by match overturn (Y. Yu and Wang, 2015). Extant live streaming literature has also found that emotion-related factors impact viewers' behaviors (e.g., commenting, continuous watching, and gifting). For example, a sense of community and social anxiety have been empirically confirmed to motivate viewers to engage in gaming live streaming (Hilvert-Bruce et al. 2018). Apart from that, emotional support and affection would stimulate more consumption of virtual gifts from viewers (Wohn et al., 2018). Recently, an empirical study found that live streaming could amplify viewers' emotions, which may further stimulate viewers' tipping behaviors (Lin et al., 2021).

In our research context, the emotion of viewers could be expressed in their comments, and emotional arousal is the extent to which an individual's emotion is intensified (Yin et al., 2017). Streamers could indirectly alter viewers' gifting or tipping behavior via arousing emotions (Lin et al., 2021; Wohn et al., 2018). Meanwhile, the gamified competition form of performance in PK could serve to enrich the live streaming content with performed competition and streamer interactions. A streamer individually communicates with viewers via response to their gifts or comments in typical ELS settings. In contrast, the streamer could team with other streamers to present co-created content in PK for entertaining viewers. It suggests that PK particularly highlights the importance of arousing collective emotion efficiently for boosting revenue. In this study, we regard PK as a unique ELS task, i.e., an emotional arousal task requiring team collaboration.

Shared Experience in PK

A sizable body of team experience studies yielded empirical evidence for the impact of prior collaboration interactions on performance (e.g., Honoré, 2020; Huckman et al., 2008; Madiedo et al., 2020). PK allows streamers to collaboratively create content while this process is presented live to entertain viewers. However, there is a lack of research on studying the mechanism behind PK, a novel form of teamwork task as an entertainment service. Concerning team experience in PK, we focus on studying shared PK experiences that streamers cumulated in repeating PK tasks as a stable team. Team familiarity refers to the degree to which individuals have worked as a team over the past (Huckman et al., 2008). As a team involves in a task that demands joint efforts and shared knowledge, familiarity could improve the team's ability to coordinate with technical knowledge transfer (Huckman et al., 2008). For instance, researchers found that when a group of colleagues could possess shared experience, including a common working routine, which benefits their later team outcomes (Agarwal et al., 2015; Honoré, 2020). PK task repetition may help a streamer team develop a shared routine for content creation in PK and exchange information on emotional arousal techniques, thereby contributing to later revenue growth.

PK, an ELS task, entertains viewers by presenting streamers' interactions in real time. It means that a successful team task requires both smooth coordination and entertaining content. Building on familiarity gained from shared PK experience, a PK team may improve the coordination ability to favor later task execution (Honoré, 2020; Madiedo et al., 2020), like a live sports game broadcast. However, the repetitive appearance of the same PK team may indicate content overlap and reduce viewers' curiosity. Previous studies in marketing found that such repetition could wear out consumers (e.g., Chae et al., 2018; Yaveroglu and Donthu, 2008), and decreased content freshness negatively impacted the popularity of web content (Du, 2014). In this study, we examine the impact of shared PK experience by considering a non-linear relationship between it and emotional arousal.

In addition, there is a lack of research on the revenue growth caused by the collaborative performance of ELS events. Previous studies have drawn attention to general viewer engagement, such as commenting (e.g., Zhou et al., 2019), continuously watching (e.g., Hu et al., 2017), and gifting or tipping revenues (e.g., Lin et al., 2021; Zhou et al., 2019). Researchers neglected the revenue growth resulting from streamer collaboration. *Revenue growth* refers to the virtual gift or tipping income change a PK event brings. To fill

this research gap, our research focused on the influence of shared PK experience on the revenue growth for streamers earned from PK events. The gamified competition form of performance in PK could add value to gifting or tipping behavior since it could help a streamer win (Lee et al., 2018). Apart from that, PK induces more stimuli in content by performing competitive interactions between streamers than ordinary ELS content. A recent empirical study found that aroused collective emotion could positively contribute to live streaming revenue (Lin et al., 2021), suggesting that PK may contribute to higher revenue than ordinary individual events. As such, it is imperative to investigate how viewers' emotional arousal leads to revenue growth of streamers in a PK event.

Research Model and Hypotheses Development

We constitute a research model (in Figure 2) including a curvilinear relationship between shared PK experience and emotional arousal, which is positively associated with revenue growth. Moreover, experience acquisition difference moderates the curvilinear relationship between shared PK experience and emotional arousal.

Figure 2. Research Model
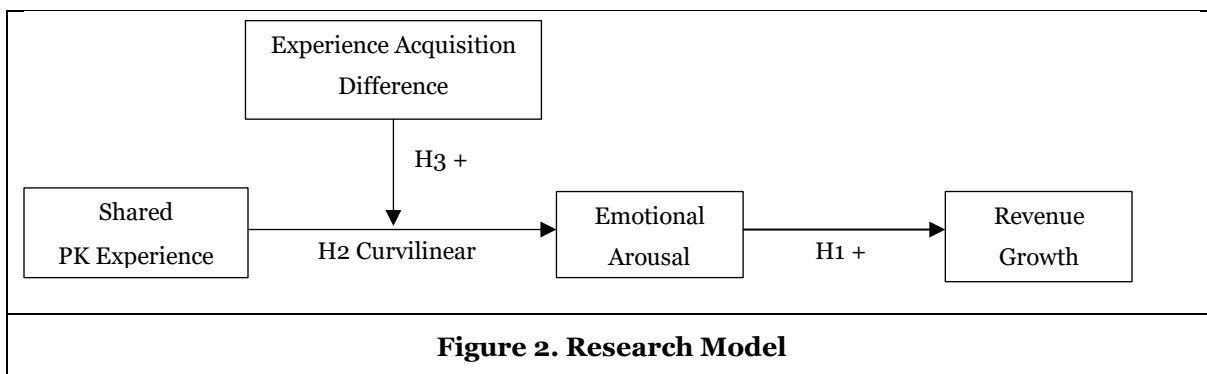
In PK, two streamers can competitively offer talent shows. With a high level of emotional arousal, engaged and excited viewers would be more likely to impulsively send virtual gifts to their favored streamer to help the streamer win this event, which in turn facilitates a higher gifting revenue (Lin et al., 2021; Zhang et al., 2019). Then, we hypothesize that intensified viewer emotion improves a streamer's revenue growth:

Hypothesis 1 (H1): *Emotional arousal is positively associated with revenue growth.*

Extrapolated to the context of ELS, we decomposed the impact of shared PK experience on emotional arousal with the countervailing effect of freshness and familiarity. The benefit of familiarity outweighs the negative effect of freshness loss at the early stage of PK team repetition. Viewers are still curious about forming a new streamer team, while within-streamer familiarity keeps growing with increased shared PK experience, starting from an unacquainted state. Team familiarity could lead to better information exchange and tacit understanding, which are beneficial for collaboration (Akgün et al., 2015; Honoré, 2020; Huckman et al., 2008; Reagans et al., 2005; Shah et al., 2019). For example, when streamers are familiar with each other's communication styles, they would understand each other's ideas faster and more efficiently intensify the viewer's emotion. Moreover, once two streamers are more familiar with each other's capabilities and weaknesses, they may improve their performance complementarily. Hence, their content co-creation would be smoother when entertaining viewers. The familiarity level increases rapidly as streamers in a new team are motivated to learn more about each other. Meanwhile, freshness drops slowly as viewers are still curious about a new PK team. It suggests that, at this stage, a longer shared PK experience positively impacts conduct emotional arousal in PK.

After the highest point, the emotional arousal level could turn to decrease as shared PK experiences increase over time. Considering that content repetition due to PK team recurrent appearance may wear out viewers (Chae et al., 2018; Du, 2014), their emotional arousal level would be reduced as shared PK experience increases. For example, viewers would lose patience when they are accustomed to the routine gimmicks of the team, thus, shifting their attention to other streamers. This could result in a situation where freshness drops sharply as and surpasses the benefit of familiarity increase. Therefore, when the shared PK experience increases, it may first positively contribute to emotional arousal and start decreasing after a certain point. Building on that, we hypothesize:

Hypothesis 2 (H2): *Shared PK experience has an inverted U-shaped relationship with emotional arousal.*

Combining H1 and H2, we propose that emotional arousal mediates between shared PK experience and revenue growth. That is, shared PK experience has an indirect inverted U-shaped relationship with revenue growth via emotional arousal.

Prior literature argued that the balance of variety and specialization is vital for individuals' experience accumulation to improve creativity and productivity (Jain and Mitchell, 2022; KC and Staats, 2012). ELS platforms require a streamer to choose a content category (e.g., game playing and talent show) and create live content accordingly. Meanwhile, streamers clustered in content categories tend to develop their routine way of completing PK tasks. For instance, streamers in the talent show category usually perform the same dance moves in turn, while streamers in the chatting category may opt for quizzes instead. A streamer could choose to allocate time to learn PK routines and tacit from either a certain category (i.e., specialization) or a wide range of categories (i.e., variety). Individual differences in relative exposure to specialization versus variety at the team level might influence team outcomes (Fahrenkopf et al., 2020; Tiwana and McLean, 2005). For adopting PK to aid content creation, streamers need to be able to extract category-featured PK skills while interacting with team members in PK. When streamers gather and interact as a team in PK, the experience acquisition difference contributes to the PK task: a larger within-team difference may indicate more exciting and creative content created with diverse ideas, perspectives, and innovation (Tiwana and McLean, 2005). For example, teaming with variety-favored streamers may help specialization-favored streamers to disrupt routines and try new tacit (e.g., streamers in the chatting category try dance battle). This may alleviate the speed of freshness loss with the increased creativity and help the formation team familiarity with the constructive conversation, flattening the inverted U-curve we hypothesized above. Thus, we posit that:

Hypothesis 3 (H3): *Experience acquisition difference positively moderates the inverted U-shaped relationship between shared PK experience and emotional arousal.*

Methodology

Data Collection

To validate our research model, we used a dataset containing streamers' PK records from a leading ELS platform (hereafter "*Platform LiveStream*"[1]) in China, which had over 20,000 active streamers and attracted around 300 million registered users by the end of 2019. *Platform LiveStream* introduced its PK function in June 2017. PK on this platform has gradually grown to the extent that streamers conducted nearly 20,000 PK events in one day. A streamer in *Platform Livestream* could initiate a PK by forming a dyadic PK team. PK in *Platform LiveStream* is a version with two streamers proactively matching to perform gamified competition for a higher value of virtual gifts. As displayed in Figure 3, a real-time PK score showing the gifting revenue of each streamer highlights the ongoing PK process.

We collaborated with *Platform LiveStream* to collect a sample of PK records from October 1st to December 31st in 2019. The dataset contained streamers' background information (i.e., self-reported age, gender, content category, guild ID, and follower number), comments sent by viewers in PK events, and virtual gift records at the platform level. Due to the data confidentiality agreements, we use encrypted hard-drive and on-site data collection from its data warehouse. The firm anonymized streamer IDs, user IDs, and other sensitive information. Observations with missing values in streamers' demographic information have also been removed. Finally, our validated sample included 118,323 PK records of 72,246 streamer dyadic teams.

Measures

Revenue growth. Consistent with extant literature, we used the monetary value of virtual gifts (prices ranging from 0.1 CNY to 1,000 CNY) to measure ELS performance (E. Yu et al., 2018; Zhou et al., 2019). We evaluated revenue growth by calculating the differences between total team income in PK and expected gift income in ordinary live streaming for a streamer within the same time length. We then deducted the

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[1] Due to the data confidentiality agreements with the live streaming platform, we anonymized our data source in this manuscript.

expected gift income in ordinary live streaming to control the streamer's ordinary revenue level in persuading viewers' tipping behavior, thereby reflecting the net revenue from the PK event. The expected gift income was estimated by the average gift income per minute and PK time length.

Figure 3. PK Interface in the Platform

Shared PK experience. The independent variable was the total time length in hours of all past PK events that two streamers paired together. During task repetition, streamers could accumulate task-related experience as a team (Reagans et al., 2005).

Experience acquisition difference. In our study, we adopted the Herfindahl-Hirschman Index (HHI), which was used to gauge the market concentration level, to measure the relative degree of a streamer's exposure to variety versus specialization (Narayanan et al., 2009). Instead of market share, we used time spent with streamers from different categories to calculate HHI, which was calculated as the sum of squared time length spent with each content category relative to total past PK time length (1: entertainment; 2: yanzhi (beautifulness); 3: others). HHI=1 when a streamer completes PK with members from only one category; HHI decreases lowest at 1/N when the streamer's time allocation is equally disparate across categories (N: the total number of categories). We further operationalized experience acquisition difference as the absolute difference between two streamers' HHIs.

Emotional arousal. Emotion arousal was gauged by the level of emotionality embodied in viewers' comments, which served as the primary way for viewers to express their feelings. We used sentiment analysis to quantify emotional intensity, particularly in comments texts to reflect collective emotion arousal levels based on prior studies (Lin et al., 2021; Warriner et al., 2013). We aggregated the absolute sentiment scores of all comments sent to a PK event to measure the emotional arousal level. The collected comments were in Chinese and contained many contextualized terms and phrases. Thus, we adopted a sentiment analysis algorithm named *bixin*[2] and manually updated the sentiment dictionary with the following steps: 1) separated and counted words in comments; 2) the top 100 phrases or words were manually categorized as positive or negative words; 3) categorized words into the sentiment dictionary; 4) randomly selected 200 comments and invited three volunteers to manually categorize them, 5) an average accuracy of around 70% has been reached. In other words, we have refined the dictionary for sentiment analysis in terms of our research context. We used the aggregated absolute value of all sentiment scores during a PK event as a proxy for emotional arousal. Due to the high skewness in the distribution, we applied log-transformed in the form of ln(x+1) for this variable (Becker et al., 2019).

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[2] Accessible: https://github.com/bung87/bixin

Variable	Description	Operationalization
Revenue growth$_{i,t}$	Total value of virtual gifts received (RMB) by PK team k in this PK event minus the team expected to earn (RMB) in ordinary live streaming events (calculated based on average gifting performance 24 hours ahead of current PK event) given the same time.	$Expected\ total\ gift\ value\ _{i,t,s}$ $= \left(\dfrac{\sum_{t-1}^{T}(Total\ gift\ value\ _i)}{\sum_{t-1}^{T}(PK\ time\ length\ _i)} \right.$ $\left. * PK\ time\ length_{i,t} \right)$ $PK\ performance_{i,t} = \dfrac{Total\ gift\ value_{i,t}}{\sum_{s=1}^{2} Expected\ gift\ value_{i,t,s}}$
Lagged revenue growth$_{i,\,t-1}$	The revenue growth of the PK team i's last PK event at t-1 (RMB)	N/A
Shared PK experience$_{i,t}$	Total accumulated PK time length (h) of team i at time t	N/A
Experience acquisition difference$_c$	The absolute difference between two streamers' HHIs of past cross-category PK time length disparity	$\left| \sum_{s=1,C} Share\ of\ time\ used\ in\ teaming\ with\ streamer\ in\ category_{t,c}^{2} \right.$ $\left. - \sum_{s=2,C} Share\ of\ time\ used\ in\ teaming\ with\ streamer\ in\ category_{t,c}^{2} \right|$
Emotional arousal$_{i,t}$	Total absolute sentiment score of current PK event (ln(x+1) transformed)	$\log\left(\left(\sum_{n=0}^{N} \left| sentiment\ score_{i,t,n} \right| \right) + 1 \right)$
Age$_{s=1}$	Reported age on the profile of streamer 1 in PK team k	N/A
Age$_{s=2}$	Reported age on the profile of streamer 2 in PK team k	N/A
Follower number difference$_{i,t}$	Absolute relative follower number difference of PK team i streamers (ln(x+1) transformed)	$\log\left(\left(\dfrac{\left| \begin{array}{c} follower\ number_{i,t,1} - \\ follower\ number_{i,t,2} \end{array} \right|}{\sum_{s=1}^{2} streamer\ 1\ follower\ number_{i,t,s}} \right) + 1 \right)$
PK timing$_{i,t}$	The hour (0-23) of PK starting time	N/A
Category$_{s=1}$	Content category of streamer 1	1: entertainment; 2: yanzhi (beautiness); 3: web games; 4: mobile games; 5: others.
Category$_{s=2}$	Content category of streamer 2	1: entertainment; 2: yanzhi (beautiness); 3: web games; 4: mobile games; 5: others.
Same category$_i$	Whether or not streamers are from the same content category	1: same category; 0: different categories
Table 1. Operationalization of Variables		

Note: i: PK team indicator; t: PK event time indicator; T: one day ahead of starting time of PK event$_{i,t}$; s: streamer indicator in PK team i; n: the number of comments; c: category type indicator (1: entertainment; 2: yanzhi (beautifulness); 3: web games; 4: mobile games; 5: others). All-time length variables are in hours. ln(x+1) transformation is applied for skewed variables with ln0 having no special meaning.

Control variables. We reviewed previous live streaming studies on streamer characteristics and controlled variables, including age and follower number difference, accounting for the variation in dyadic characteristics. As for event characteristics, previous studies denote the live streaming event's schedule is important for both viewers and streamers. We thus control the hour of the day that a PK event starts (Kim et al., 2019; Striner et al., 2021). Meanwhile, viewer emotion stimulated in ELS may have a lagged effect on later performance (Lin et al., 2021). Considering that the performance of the PK team's last PK event may also have a lagged impact on the current PK event's performance, thus, we also controlled the effect of the lagged PK event performance.

Analytical Method

As we investigate how revenue growth varied as the shared PK experience of a PK team increased over time, all key variables in our model are at level 1 (i.e., the team-event level). We coded each PK team with a unique ID for analysis, PK event data samples are nested within specific PK teams (level 2). We conducted a likelihood ratio test (LRT), and the significance of the chi-square (p<0.001) legitimates a multilevel model fit better than a simpler one (LaHuis and Ferguson, 2007). According to the "Predictor-Mediator-Outcome" format for multilevel models, our proposed model could be classified as "1-1-1" with all critical variables at level-1 (team-event level) (Krull and MacKinnon, 2001). For the 1-1-1 model, aggregating level 1 data at level 2 may lead to false rejection of the hypothesis, both multilevel linear model (MLM) and multilevel structural equation modeling (MSEM) are thus preferable (Zigler and Ye, 2019). We adopted MLM for hypothesis testing with the maximum likelihood estimation method and presented MSEM results for robustness check (see Appendix) (Rabe-Hesketh and Skrondal, 2008). For testing our hypotheses, we applied the three-step method to examine emotional arousal's mediating role, then added interaction terms to test the moderating effect of experience acquisition difference (Baron and Kenny, 1986; Zigler and Ye, 2019).

Results

Table 2 presents the descriptive statistics and correlation matrix of continuous variables. The mean and standard deviations were calculated at the team-event level. Since there was significant within-team variation in most variables except streamers' age, the relationships among aggregated variables (i.e., correlations) did not represent proper within-team relationships.

	Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9
1	Revenue growth	-99.83	141.55	1								
2	Lagged revenue growth	-101.24	143.62	0.398	1							
3	Shared PK experience	0.56	0.81	-0.004	-0.008	1						
4	Emotional arousal	0.05	0.35	0.012	-0.015	0.003	1					
5	EAD	0.06	0.09	0.061	0.072	0.021	-0.003	1				
6	$Age_{s=1}$	25.75	6.39	-0.001	-0.008	-0.015	0.000	0.007	1			
7	$Age_{s=2}$	26.00	6.55	0.000	-0.001	-0.009	0.011	0.016	0.017	1		
8	Follower number difference	0.12	0.85	0.036	0.039	-0.034	-0.004	0.067	-0.010	-0.011	1	
9	PK timing	11.98	5.40	-0.082	-0.089	0.011	0.041	0.028	-0.013	0.012	-0.015	1

Table 2. Means, Standard Deviations, and Correlation Matrix

Note: EAD: Experience Acquisition Difference.

Table 3 shows the MLM analysis results. Model 1 to Model 3 presents the results of the three–step method for testing the mediating effect of emotional arousal. By treating shared PK experience as the time variable, we investigated the growth trajectories of PK revenue (Model 1 and 3) and emotional arousal (Model 2). We translated the testing of the curvilinear relationship posited in hypotheses into the examination of a quadratic growth trajectory. We tested the relationship between shared PK experience and revenue growth for the first step. Model 1 showed that the quadratic growth in PK revenue as shared PK experience increased was significant ($\beta_2 = 1.866$, standard error=0.360, $p < 0.01$, in Model 1). This result indicates when shared PK experience accumulates from zero, the revenue growth of PK tasks decreases at first; once the time spent as a team exceeds 1.89h (hour), revenue growth started to grow after hitting the lowest point (i.e., -232.527RMB). In the second step, we estimated a quadratic growth trajectory of emotional arousal as shared PK experience accumulates for testing Hypothesis 2. The squared term of shared PK experience in Model 2 was significant ($\beta_2 = -0.003$, standard error=0.001, $p < 0.01$, in Model 2). As shown in Figure 4, accumulating experience as a new team (from 0 to 2h) contributes to an increase in emotional arousal with diminishing margins; however, as shared PK experience climbs to 2 hours, emotional arousal will reach the highest point of 0.057; further, the relationship between shared PK experience and emotional arousal showed a declining trend with shared PK experience longer than 2h. Thus, the results attested to the

inverted U-shaped relation between shared PK experience and emotional arousal, supporting Hypothesis 2. In the third step, Model 3 presents the results of testing Hypothesis 1. Emotional arousal (β_3 = 9.894, standard error=1.857, $p < 0.01$, in Model 3) was significantly related to revenue growth. The overall three-step results indicate a significant partial mediation role of emotional arousal. Overall, the result supported the mediation role that emotional arousal played in the relationship between shared PK experience and revenue growth that we posited in Hypothesis 3. Further, the direct U-shaped relationship between shared PK experience and revenue growth was significant in Models 1 and 3. Decreased values of the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) support a partial mediation effect with better model performance (LaHuis and Ferguson, 2007).

Parameters	Model 1	Model 2	Model 3	Model 4	Model 5
	Revenue growth	Emotional arousal	Revenue growth	Emotional arousal	Revenue growth
Shared PK experience (β_1)	-7.089***	0.012***	-5.044**	0.022***	-9.308***
Shared PK experience^2 (β_2)	1.866***	-0.003***	1.521***	-0.006***	2.459***
Emotional arousal (β_3)			9.894***		8.262***
EAD (β_4)				0.026	45.330***
Shared PK experience × EAD (β_5)				-0.152***	34.333**
Shared PK experience^2 × EAD (β_6)				0.042***	-8.802*
Control variables:					
Lagged revenue growth	0.320***	<0.001***	0.321***	<0.001***	0.319***
Age$_{s=1}$	0.087	<0.001	0.09	<0.001	0.085
Age $_{s=2}$	0.058	0.001***	0.053	0.001***	0.046
Follower number difference	39.919***	-0.015	40.255***	-0.013	36.634***
PK timing	-1.393***	0.003***	-1.414***	0.003***	-1.434***
Category$_{s=1}$=2	3.762***	-0.002	3.755***	-0.002	3.939***
Category$_{s=1}$=3	11.676***	-0.007	11.700***	-0.007	10.241***
Category$_{s=1}$=4	24.275***	-0.016**	24.287***	-0.016**	23.727***
Category$_{s=1}$=5	29.262***	-0.006	29.202***	-0.006	28.327***
Category$_{s=2}$=2	3.261***	-0.002	3.252***	-0.002	3.438***
Category$_{s=2}$=3	5.373*	0.016*	5.179*	0.016**	3.006
Category$_{s=2}$=4	22.233***	0.001	22.070***	0.001	21.543***
Category$_{s=2}$=5	26.789***	0.001	26.639***	0.001	25.505***
Same category=1	-0.044	0.002	-0.103	0.002	-0.477
Intercept	-60.048***	-0.119	-60.061***	-0.004	-62.389***
AIC	498,951	26,692	498,924	26,711	498,863
BIC	499,115	26,864	499,104	26,909	499,061

Table 3. Results from Multilevel Linear Modeling

Note: Sample N = 118,323; *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; EAD: Experience Acquisition Difference; AIC: Akaike Information Criterion; BIC: Bayesian Information Criterion.

We examined the moderating effect of experience acquisition difference with results shown in Model 4. The significance of the interaction term between squared shared PK experience and experience acquisition

difference suggests that experience acquisition difference positively moderated the curvilinear relationship between shared PK experience and emotional arousal. Consisting with H3, the interaction term of squared shared PK experience and experience acquisition difference was significant ($\beta_6 = 0.042$, standard error=0.013, $p < 0.01$, in Model 4). As displayed in Figure 5, we further examined the moderation effect at the difference between low, middle, and high levels of knowledge acquisition. Experience acquisition difference amplified the curvilinear relationship such that a shape-flip phenomenon was observed (Haans et al., 2016). From the low to intermediate level of experience acquisition difference, shared PK experience and emotional arousal had a flattened inverted U-shaped relationship. Instead, their relationship was flipped to a U-shaped one, given a high experience acquisition difference. Additionally, results in Model 5 support the whole model we posited with the significance of all coefficients.
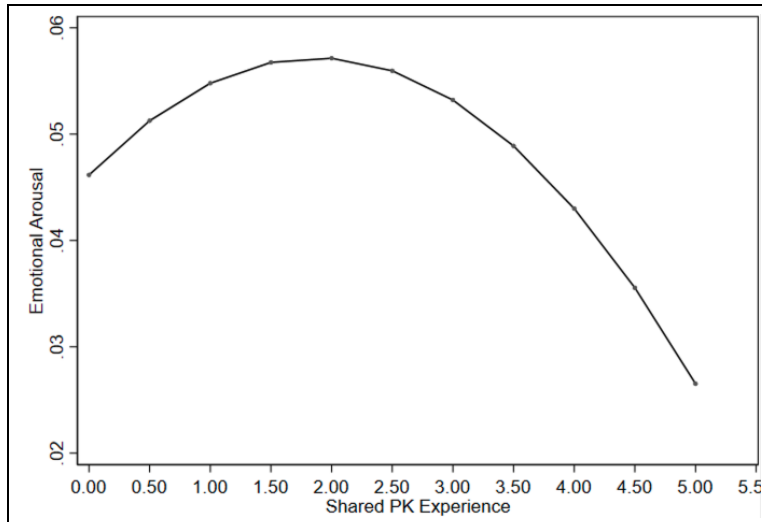

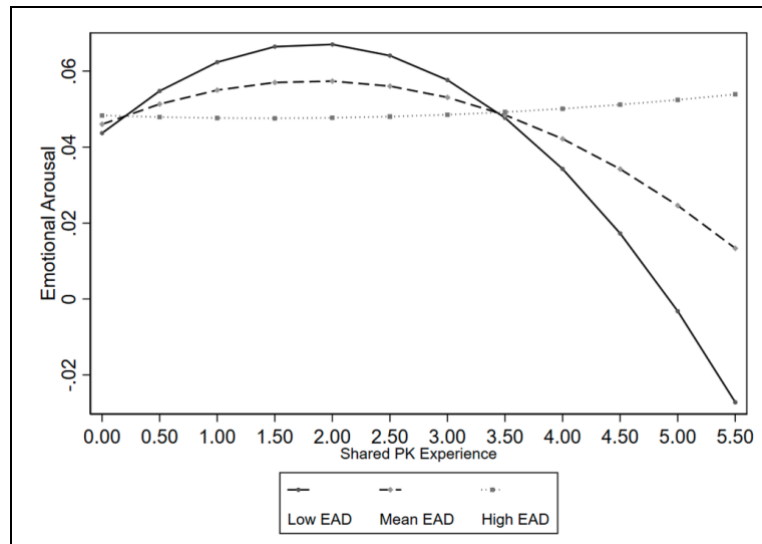**Figure 4. Growth Curve of Emotional Arousal**

Figure 5. Moderated Growth Curve of Emotional Arousal with Experience Acquisition Difference (EAD) as the Moderator

Discussion

Our study scrutinizes the relationship between shared PK experience and emotional arousal, which in turn relates to revenue growth. In addition, the moderating role of experience acquisition difference is investigated in this research. We collected data from 118,323 PK records from a leading Chinese ELS platform for analysis to examine the proposed hypotheses. Extending the non-linear effect of experience generated from the workplace contexts (e.g., Ng and Feldman, 2010; Xie et al. 2020), we find interesting results in the live streaming context. First, shared PK experience influences emotional arousal and indirectly improves revenue growth. Consistent with previous findings (Lin et al., 2021), we confirm that viewers' emotional arousal could relate to revenue growth. Second, this study unravels an inverted U-shaped relationship between shared PK experience and emotional arousal. The level of emotional arousal is the lowest at a medium level of shared PK experience. Third, we reveal that experience acquisition difference plays a moderation role in the curvilinear relationship between shared PK experience and emotional arousal, with an interesting shape-flip effect observed. A high level of experience acquisition difference may delay the formation of team familiarity. Although team members could absorb external knowledge for better teamwork decisions, task collaboration may be hindered due to excessive ideas and potential conflicts generated by external knowledge (Haas, 2010). Given that, the effect of freshness loss will dominate with a decreasing benefit from PK team repetition at the early stage of cumulating shared PK experience. As shared PK experience further increases, familiarity starts to take a greater effect after overcoming conflicts brought by the significant experience acquisition difference, turning revenue growth to increase instead. Taken together, there would be a U-shaped relationship between shared PK experience and emotional arousal when the experience acquisition difference is high. For instance, most experienced streamers in PK teamed with novice streamers in a team (Haas, 2010). The experienced ones may try to control the PK content creation over the novice ones, which could lead to conflicting views on how to complete PK and their team collaboration.

Theoretical Implications

First, this study extends the live streaming literature by investigating team collaboration from the perspective of shared team experience. Prior live streaming studies focus on the impact exerted by individual streamers on viewer engagement (Hilvert-Bruce et al., 2018), omitting the potential of investigating their collaborative impact through a teamwork lens. Our study enriches this research stream by attesting the role of teamwork in revenue growth using a large-scale dataset.

Second, this study disentangles the curvilinear pattern of emotional arousal as shared PK experience cumulates. It provides insights on leveraging shared PK experience to entice viewers' emotional arousal in ELS. We develop the research model based on experience literature, aiming to contribute to live streaming studies by delineating the complicated role of shared PK experience in influencing emotional arousal.

Third, we extend past literature on the importance of working with teammates from the on-site workplace to the online live streaming context (Guchait et al., 2016; Postrel, 2002). We consider teaming with streamers from different content categories diversity as a diverse knowledge source for improving emotional arousal ability. By examining the moderating role of experience acquisition differences, this study supports the importance of within-team experience acquisition differences embodied in team composition. Thus, we enrich the literature on knowledge acquisition at the team level by exploring its impact on virtual teamwork in the entertainment industry.

Managerial Implications

ELS platforms and streamers are keen on utilizing PK events as a content-enriching tool by fueling a dynamic atmosphere. The findings of this study have insightful implications for both streamers and live streaming platforms. ELS platforms need to be cautious about the PK team member recommendation strategy of PK. When deciding whether encourage a streamer team repeatedly conducting PK events, the platform need to balance between the positive effect of familiarity increment and the negative effect of freshness diminishment. Apart from that, our findings on the moderating role of experience acquisition difference suggest that streamers could team with others with a different level of knowledge absorbed from previous cross-category PK events to offset the content freshness loss of repeated team appearance.

ELS platforms should optimize their matchmaking algorithms to help streamers strategically plan their PK events with different partners. Considering the inverted U-shaped relationship between shared PK experience and emotional arousal, platforms could help streamers to overcome the negative impact of repeated PK events by providing monetary rewards until the turning point arrives. After several repeated PK events, platforms could encourage streamers to team with their familiar partners to sustain a long-term beneficial collaboration. Besides, our results indicate the pivotal role of viewers' emotional arousal in improving PK performance. Platforms are recommended to develop more emotion-arousal tools (e.g., on-screen mini-games) for streamers to develop a dynamic atmosphere in PK events.

Limitations and Future Research

Our study has constraints and limitations that could be addressed in future research. First, we stress the mechanism behind PK as a live streaming tool used by streamers with data collected from this specific function from one ELS platform, which may indicate the issue of generalizability due to the variation of similar functions across platforms. For instance, streamers in KuaiShou and TikTok compete for virtual gifts to attract followers to purchase tangible products. Future studies are encouraged to validate our research model in different variants of PK events to explore its applicability to other contexts. Second, this study investigates the influencing factors of viewers' emotional arousal from the perspective of shared experiences possessed by streamers. Although this work is pioneering to tease out how to perform repeated PK events for emotional arousal strategically, future studies could focus on the PK process. An in-depth video analysis could reveal how interactions between streamers could entice emotional arousal in real-time, thereby providing valuable recommendations on how streamers collaborate amid PK events to maximize their benefits. Third, we decipher the influencing factors of emotional arousal from the streamers' side, leaving room for future studies to investigate from viewers' perspectives. Although the experience of streamers is detrimental to revenue growth, it deserves attention regarding the interaction among viewers during PK events. For example, as emotions are contagious among viewers, future research could scrutinize how emotions are spread in PK events.

Acknowledgements

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Appendix

Multilevel Structural Equation Model Estimation Results

Parameters	DV: Emotional arousal	DV: Revenue growth
Shared PK experience (β_1)	0.022***	-10.137***
Shared PK experience^2 (β_2)	-0.006***	3.044***
Emotional arousal (β_3)		6.539***
EAD (β_4)	0.024	41.303***
Shared PK experience × EAD (β_5)	-0.147**	39.974**
Shared PK experience^2 × EAD (β_6)	0.037**	-13.047**
Control variables included		
Intercept	0.250***	-0.119

Table 4. Results from Multilevel Structural Equation Modelling

Note: Sample N = 118,323; *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; EAD: Experience Acquisition Difference; DV: Dependent Variable.