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Analyzing Consumer Feedback on Virtual Reality Devices: A Latent Dirichlet Allocation(LDA) Approach Using Chinese Social Media Data

Ji Yang*, Zhi-Zhong Xiao*, Zi-Yang Liu**

*Student, School of Global Business, Kyonggi University, Suwon, Korea
**Professor, Dept. of Global Business, Kyonggi University, Suwon, Korea

[Abstract]

This study explores consumer attitudes toward virtual reality (VR) devices by analyzing user comments text from China's Bilibili platform. Using the Latent Dirichlet Allocation (LDA) topic model, it identifies four key areas of focus: (1) performance and immersive experience, covering video quality, gaming latency, and network stability; (2) brand innovation and technological progress, featuring companies like Apple, Huawei, and Sony; (3) health and usage factors, including eye comfort and spatial needs; and (4) content ecosystem and promotion, addressing video diversity and marketing strategies. The analysis reveals that consumers prioritize high-performing hardware for immersion, reliable network support, and ergonomic design to mitigate eye strain, alongside accessible content. This social media text-mining approach fills a gap in VR user feedback research, providing manufacturers with actionable insights for optimizing device performance and health features, while informing content creators about user preferences. Innovatively, it links cultural influences to technology adoption, offering practical recommendations for product enhancements and new research directions for the global VR industry's development.

▸ **Key words**: Virtual reality(VR), Latent Dirichlet Allocation(LDA), Social media, Consumer needs

[요 약]

본 연구는 중국의 Bilibili 플랫폼에서 수집한 사용자 댓글을 바탕으로 가상현실(VR) 기기에 대한 소비자 태도를 분석하였다. 잠재 디리클레 할당(LDA) 토픽 모델을 활용한 결과, 주요 논의 주제는 네 가지로 도출되었다. 첫째, 영상 품질, 게임 지연, 네트워크 안정성 등과 관련된 성능 및 몰입 경험. 둘째, 애플, 화웨이, 소니 등 주요 기업을 중심으로 한 브랜드 혁신과 기술 발전. 셋째, 시각적 피로 완화와 공간 활용성 등 사용자 건강 및 편의성과 관련된 요소. 넷째, 콘텐츠 다양성과 마케팅 전략을 포함한 콘텐츠 생태계 및 프로모션 전략이다. 분석 결과, 소비자들은 몰입 경험을 극대화할 수 있는 고성능 하드웨어, 안정적인 네트워크 환경, 인체공학적 설계를 기반으로 한 시각적 편안함, 그리고 접근성이 높은 콘텐츠를 핵심 요소로 인식하고 있었다. 이러한 소셜미디어 기반 텍스트 마이닝 접근은 VR 사용자 경험에 대한 기존 연구의 한계를 보완하며, 제조업체에는 성능 및 건강 기능 개선을 위한 실질적 시사점을, 콘텐츠 제작자에게는 사용자 수요에 기반한 창작 방향을 제시한다. 나아가, 본 연구는 기술 수용 과정에서 문화적 요인이 미치는 영향을 강조함으로써, 향후 글로벌 VR 산업 발전과 제품 혁신을 위한 새로운 연구 가능성을 제안하였다.

▸ **주제어**: 가상 현실(VR), 잠재 디리클레 할당(LDA), 사회관계망 서비스(SNS), 소비자 니즈

• First Author: Ji Yang, Corresponding Author: Zi-Yang Liu
*Ji Yang (297179390@qq.com), School of Global Business, Kyonggi University
*Zhi-Zhong Xiao (469320047@qq.com), School of Global Business, Kyonggi University
**Zi-Yang Liu (morninglzy@hotmail.com), Dept. of Global Business, Kyonggi University
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I. Introduction

The digital transformation of the Fourth Industrial Revolution is reshaping the development of the technology consumption sector. Virtual reality (VR) technology has evolved from early industrial and professional uses to the mass consumer market. Modern VR headsets are portable, offer entertainment features, and have acceptable prices. Consumers now use them widely in daily life. As a mature and accessible technology, VR provides advanced functional features [1]. Currently, VR devices are applied in gaming, virtual tourism, education, and social interaction. Their core features include immersive experiences, presence, and interactivity [2]. These traits offer new perspectives for studying consumer preferences and behavior. Analysis of user discussions on social media can reveal authentic experiences and needs related to VR devices.

In recent years, the application of virtual reality (VR) technology has expanded across education, retail, and digital consumption, drawing increasing scholarly attention to how its immersive features influence user behavior. In educational contexts, studies have shown that factors such as usability, immersion, and ease of use significantly affect learners' interactions with VR devices in unsupervised online environments [3]. Complementary research further suggests that hands-on interface training can enhance users' sense of presence and learning performance while reducing extraneous cognitive load [4]. In the consumer domain, immersive technologies are no longer regarded merely as novelty tools but are becoming integral to everyday consumer engagement. A comprehensive review highlights that AR, VR, MR, and 3D technologies are reshaping consumers' perceptual and decision-making processes across industries [5].Specifically, emotional states and gender identity have been found to interact with immersion levels in VR retail settings, significantly influencing impulsive purchasing behavior [6]. Moreover, auditory cues such as voice gender and pitch in virtual shopping assistants affect purchase intention through perceived competence, sociability, and moral evaluations [7]. While these studies have contributed to a broader understanding of VR in educational and consumer research, most rely on controlled experimental conditions. There remains a notable lack of research that systematically examines users' natural responses within real-world usage scenarios, particularly those expressed through user-generated content on social media platforms.

Social media has become a key channel for users to share experiences and reviews due to the rapid growth of video platforms. Video reviews, guides, and user comments on these platforms offer consumers multidimensional product information and practical usage insights [8]. These comments reveal user focus on VR devices. They also provide direct evidence for manufacturers to improve products and services. Currently, large amounts of user-generated content (UGC) appear on platforms like YouTube, Reddit, and Bilibili. Bilibili, a leading Chinese platform for anime, gaming, and subculture communities, has users with a strong interest in VR device content. This creates a rich data source for extracting structured information from social media comments. However, despite the research value of social media comments, academic studies on their systematic analysis remain limited.

This study uses user comments from the Bilibili platform as a data source. It analyzes consumer focus and attitudes toward VR devices. By applying the LDA topic model to comments on VR device review videos, this study identifies key user concerns. It also examines how cultural factors influence VR device usage behavior. Bilibili is a core platform for China's subculture community. Its users show strong interest in anime and gaming, key areas for VR technology. This offers a unique perspective on the relationship between culture and

technology acceptance.

This study's innovation lies in three aspects. First, it applies text mining to social media comment analysis. This fills a gap in academic research on VR device user needs based on UGC. Second, it uses LDA topic model analysis to offer VR manufacturers suggestions for technical improvements and marketing strategies. It also helps content creators understand user needs better. Third, it analyzes Bilibili user feedback from a cultural perspective. This explores how culture affects technology acceptance. It provides a new research direction for the global development of the VR industry.

II. Literature review

1. Development and Popularization of VR Devices

In VR technology, users immerse themselves in a three-dimensional virtual environment. They navigate and interact to experience multi-sensory stimulation [9]. VR is a computer-generated simulation technology. Users perceive the virtual environment through one or more senses, primarily vision and hearing. They interact with it in a near-realistic way [10]. Specifically, VR is an immersive digital media technology. It generates three-dimensional effects. Users perceive and interact with the virtual environment. The experience resembles real-world perception. This technology lets users process virtual visual stimuli. They navigate naturally in the virtual space. For example, users can feel present in another location, like a tourism destination, regardless of their physical position. They observe the environment in a realistic way, such as looking around by moving their head. Additionally, users can take on different roles through virtual avatars. This allows them to experience alternative life scenarios [11].

In recent years, wearable VR glasses have entered the consumer market. These devices are a form of wearable technology. They enable users to experience and interact with immersive virtual environments from a first-person perspective. Typical VR devices include head-mounted displays (HMDs) with independent computing and display capabilities. Other low-cost options use smartphones with holders, like Google Cardboard, to achieve similar functions. Major global tech companies have established VR research teams or departments. These include Google, Apple, Facebook (now Meta), Amazon, Microsoft, Sony, and Samsung. Goldman Sachs predicts that by 2025, the AR and VR market will reach $80 billion. This matches the current size of the PC market [11].

Research shows that various VR applications have been developed. These cover 360-degree videos, gaming, education, and tourism. Existing studies explore the antecedents and outcomes of VR in different contexts. However, they often focus on specific applications. The role of the devices themselves receives less attention. For instance, some scholars use the TAM to study VR applications in Second Life [12]. Others focus on VR in healthcare [13] and education [14]. Still, research on overall user reactions to VR devices remains limited. We argue this is a key gap in the literature. Consumer reactions to VR devices directly affect their future use or non-use behavior.

2. LDA Topic Model Analysis

LDA (Latent Dirichlet Allocation) is a widely used topic model. It extends probabilistic latent semantic analysis (PLSA) to address issues in text mining. As an unsupervised machine learning technique, LDA identifies hidden thematic information in large document sets or corpora. It reveals internal similarities in the data [15]. The LDA model is applied in natural language processing, text topic mining, theme identification, social media analysis, text classification, and information retrieval [16]. In this model, each document is treated as a mixture of multiple topics. These topics are automatically

determined by the LDA algorithm [17].

On social media platforms, user discussions about VR devices generate vast amounts of data. The large scale makes traditional manual analysis inefficient. LDA topic model analysis, as an effective text mining technique, processes such large-scale text data automatically. It extracts valuable insights [18]. Compared to traditional surveys, interviews, and small-sample content analysis, big data analysis offers new perspectives on consumer perceptions [19]. Traditional methods are prone to bias from researchers' subjective views during data processing. This can skew results. In contrast, LDA topic model analysis relies on mathematical models and algorithms. It provides an objective and comprehensive view of consumer opinions on VR devices. This avoids personal bias and preconceptions, ensuring accurate and reliable results [20].

Consumer expressions on social media vary widely. Some opinions and needs are not directly stated but embedded in the text. LDA topic model analysis excels at uncovering these latent insights. It reveals consumers' true thoughts and demands. This offers companies deeper market understanding. Such depth is hard to achieve with traditional market research or surveys.

Discussions about VR devices on social media reflect dynamic changes and trends in the VR market. Results from LDA topic model analysis help companies craft targeted marketing strategies. For example, if analysis shows high consumer focus on the immersive experience of VR devices, companies can emphasize this feature in marketing. They can create related promotional content to attract attention. This boosts marketing effectiveness.

III. Methods and analysis

1. Selection of Data Collection Website

This study selects the Bilibili website for specific reasons. Bilibili hosts a large and highly active group of young users. These users are enthusiastic about new tech products. VR devices, as cutting-edge technology, draw their attention. They form a core potential consumer base for VR devices. These young users willingly share usage experiences on the platform. Their review comments are authentic and representative. They accurately reflect target users' views and needs for VR devices. This provides firsthand and reliable data for the study. In terms of content, Bilibili offers diverse VR device reviews. These range from unboxing experiences and real-use feedback to performance tests and brand comparisons. They cover VR device usage across various scenarios. The platform's strong interactivity fosters frequent user discussions and replies. This reveals deeper insights and hidden needs. It allows the study to explore users' true thoughts on VR devices in depth.

2. Data Collection and Processing

All data for this analysis come from the Bilibili website. First, searches were conducted on the platform using "VR device reviews" and "VR device unboxing" as keywords. Videos were filtered to the top 15 by playback volume as of August 30, 2024. Then, web scraping technology collected all comments under these 15 videos. This totaled 40,141 comments. To ensure data quality, data cleaning was performed. Comments with fewer than five characters were removed. Emojis, punctuation, and other meaningless elements were excluded. Duplicate comments were deleted [21]. After these steps, 32,557 valid comments remained.

Following data preprocessing, text data were tokenized using dictionary software. Since the collected data are primarily in Chinese, this study used the Jieba Chinese tokenization package in a Python environment. For stop word removal, common but semantically unimportant words were excluded. These include "I," "you," "he," and "this," as well as pronouns and prepositions. Additionally, words unrelated to the study were manually removed. For instance, video bloggers

offered giveaways to boost views. Giveaway-related terms in comments were added to the stop word list. This ensured more precise tokenization results.

IV. Data analysis and results

To ensure topic independence, this study combined perplexity curves with the LDAvis visualization system. This determined the optimal number of topics. First, a suitable range for the topic number k was selected using the relationship curve between perplexity and topic count. The figure below shows the consistency and perplexity of the LDA topic model across different topic numbers. To identify the best topic number, this study used Matplotlib in Python to plot a line graph. It depicted the trade-off between consistency and perplexity. The principle of high consistency and low perplexity guided the process. This study established an appropriate range for the topic number. The curve showed a clear inflection point at K=4. This suggested an optimal value. However, to ensure model rationality and effectiveness, this study set the LDA topic number to 10.

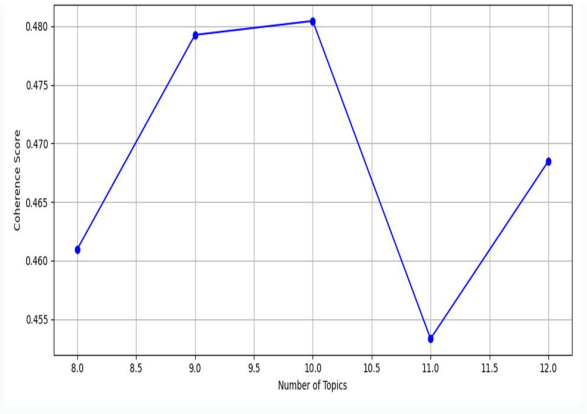

Fig. 1. Consistent results

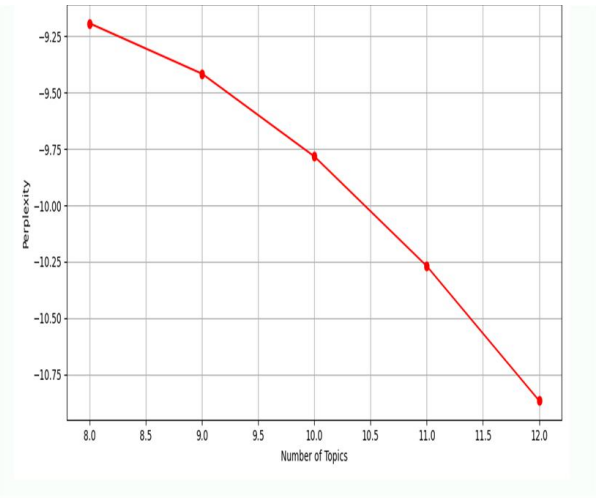

Fig. 2. Confusion results

Next, different topic numbers within this range were selected for LDA topic model analysis. To determine the topic number more intuitively, this study used the LDAvis module in Python to visualize the topic model results. Each bubble represents a topic. The bubble size shows the topic's percentage in the entire corpus. Relationships between topics appear in their positions and overlap. Large overlaps between circles indicate too many topics with redundancy. The figure below shows that with 10 topics, the classification is clear. The results are effective.

Based on feature words from LDA topic model analysis, this study combined TF-IDF word weights and text content to select sentiment topic words. It summarized the clustering results for topics related to VR devices. The table below presents these findings.

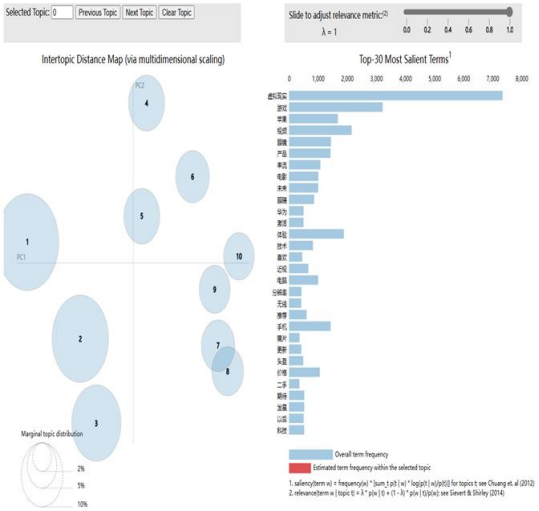

Fig. 3. Visualization of Topic Mining

Table 1. Theme clustering results

Topic	Salient terms	Human interpretation
Topic1	Film, headphones, effect, television, price, home	VR device experience and cost in home entertainment scenarios
Topic2	Streaming, resolution, wireless, clarity, router, graphics card	Network and graphics performance factors of VR devices
Topic3	Product, Apple, future, technology, expectation, development	Technological development of VR product brands
Topic4	Huawei, player, brain-computer, interface, Xiaomi, smooth	Technology and user experience of Chinese brands
Topic5	Lens, video, inexpensive, glasses, see, network	VR video experience, related accessories, and network
Topic6	Game, experience, smartphone, computer, equipment, all-in-one machine	Device support required for VR gaming experience
Topic7	Glasses, Sony, system, consider, later, account	Use of Sony VR glasses system
Topic8	Apple, world, China, demand, America, satisfy	Attention to American VR brands and products in the Chinese market
Topic9	Eye, myopia, helmet, use, space, scene	Eye protection and spatial perception in VR usage scenarios
Topic10	Activate, video, liking, advertisement, necessity, Internet	Promotion related to VR videos

Based on the topics, we grouped the above classifications into four major categories.First, the core experience and performance of VR devices include home entertainment, video experience, gaming experience, and network and graphics performance. First, in home entertainment scenarios, users expect an immersive experience from VR devices. This includes watching movies and gaming. It's the most direct use case for VR devices. Second, for video experience, users focus on VR device performance in video playback. They care about picture quality, smoothness, and immersion. Third, as a key application, VR gaming demands high performance. Users expect low latency, interactivity, and strong graphics rendering. Finally, VR devices require robust network and graphics capabilities. Users focus on wireless connectivity, router support, and graphics card performance. User comments confirm these categories. For home entertainment, one user said, "Watching movies with a VR device is great. It feels like a private theater. But it gets tiring after a while." Another noted, "My home space is small. Using a VR device for movies works fine. It's more immersive than a TV." For video experience, a user commented, "VR video quality is excellent. But some videos lack high resolution and look blurry." Another said, "3D movies work well. Wearing the headset for long feels uncomfortable." For gaming experience, a user stated, "VR gaming has low latency. It's smooth. But I feel dizzy after a while." Another pointed out, "This VR device needs a strong PC. A weak graphics card hurts the experience." For network and graphics performance, a user mentioned, "Wireless connection is stable. But the router must support Wi-Fi 6, or it lags." Another emphasized, "Graphics card performance matters a lot for VR." These comments show clear user expectations and feedback on core experience and performance.

Second, VR device brands and technological development cover brand innovation, user

experience, and market performance. First, users focus on technological innovation from VR brands. Brands like Apple, Huawei, and Sony introduce features like brain-computer interfaces and high-resolution displays. These affect device competitiveness and user appeal. Second, user experience drives VR device choice. Users expect ease of use, comfort, and rich features. Finally, users care about brand performance in the market. This includes meeting demand in China, reflecting overall brand strength. Comments also reveal trade tensions between China and the U.S. affecting product preferences. Users discuss Chinese versus American products. User comments confirm these categories. For brand innovation, one user said, "Apple's VR device tech is advanced. But it's too expensive. I hope for more innovation." Another noted, "Huawei's brain-computer interface is cool. It needs more real-world testing." For user experience, a user commented, "Sony's VR glasses are comfortable. But the system setup is complex." Another said, "Xiaomi's VR device has great value. It lacks standout features." For market performance, a user stated, "American VR brands are popular in China. But they're pricey." Another pointed out, "Chinese VR brands offer good value. Their tech needs to catch up to global standards." These comments highlight user focus on innovation, experience, and market performance.

Third, usage scenarios and eye health protection include eye protection and spatial perception. First, users worry about eye strain from prolonged VR device use. This is especially true for myopic users. Eye protection affects comfort and health, making it a key concern. Second, spatial perception matters during VR use. Users need space to avoid collisions. They evaluate device performance in spatial awareness for safety. User comments confirm these categories. For eye protection, one user said, "After an hour with a VR device, my eyes felt dry. Manufacturers should improve comfort." Another noted, "Myopic users need glasses with VR devices. It's inconvenient. I hope for adjustable focus in the future." For spatial perception, a user commented, "Playing VR games at home feels cramped. I bump into furniture." Another said, "The VR device's spatial awareness is accurate. It fails in low light." These comments show clear expectations and feedback on health protection and spatial perception.

Fourth, VR content ecosystem and promotion cover video content promotion and ecosystem development. First, users focus on the VR device content ecosystem. They care about video content richness and promotion methods. Video promotion impacts usage experience, making it a priority. Second, users want diverse content, like movies, games, and educational apps. They expect reasonable content costs. This reflects their hopes for a strong content ecosystem. User comments confirm these categories. For video content promotion, one user said, "The VR video platform has rich content. But high-quality options cost extra." Another noted, "Ads are well-promoted. I'd like more free content." For ecosystem development, a user commented, "The VR device content ecosystem isn't complete. Many apps and games feel unfinished." Another said, "I hope for more educational content. VR has big potential in education." These comments show clear expectations and feedback on content ecosystem and promotion.

V. Discussion and conclusion

1. Discussion

This study used LDA topic modeling to analyze user-generated comments on the Bilibili platform, revealing key consumer concerns regarding VR devices. These findings support and extend previous literature while offering new insights grounded in spontaneous, context-rich user feedback.

First, our results reaffirm the centrality of immersion, interactivity, and system performance in shaping user experience and acceptance of VR technology. Prior studies have emphasized the importance of immersive quality [9], technical responsiveness [10], and their relationship with perceived usefulness and ease of use [12]. This study adds value by capturing nuanced user expectations—such as stable wireless connectivity, spatial perception, visual comfort, and gaming fluency—directly expressed in natural usage scenarios. These organically formed perceptions, derived from everyday interactions rather than experimental settings, provide practical insights for manufacturers aiming to improve usability and reduce physical discomfort.

Second, the analysis sheds light on how users interpret VR brand innovation and content ecosystems through both cultural and emotional lenses. Comments reflected not only sensitivity to product functionality, but also identity-related dimensions such as national brand preference and gender perception. This aligns with previous studies on user experience [2], brand positioning [11], and R&D-driven adoption [1]. Furthermore, the feedback on virtual shopping assistants and voice cues (e.g., pitch and gender) echoes research on sensory marketing and consumer psychology [7]. In addition to confirming known influencing factors, our study shows how culture-specific communities, such as Bilibili's ACG user base, mediate the way users interpret product value and emotional fit. This highlights the need for culturally responsive design and localized marketing strategies in the global expansion of VR products.

2. Conclusion

(1) Practical Innovation

From a product optimization perspective, VR product managers can improve in several areas. First, enhance product performance. User discussions on network stability and graphics card performance show a need for better hardware compatibility and wireless technology. This ensures smoothness and stability during use. Second, address health protection design. Users raised issues like eye dryness and myopia adaptation. Managers can develop adjustable lens options or eye-protection modes. Finally, strengthen the VR content ecosystem. Managers can add educational apps and lower paid content costs. This boosts device appeal and user numbers.

From a market strategy perspective for VR products, focus on key approaches. First, increase differentiation for local brands. Chinese brands can leverage cost-effectiveness. International brands like Apple and Sony need technical innovation to justify pricing. Second, use precise promotion to capture the market. Users focus on immersive experiences. Managers can create scenario-based marketing content, like home theater or gaming demos.

From a supply chain and global layout perspective, consider trade dynamics. Amid U.S.-China tensions, local brands should accelerate independent tech development, such as brain-computer interfaces. International brands need localized supply chains to mitigate policy risks.

(2) Theoretical Innovation

Existing literature often focuses on VR technology applications or device performance optimization. This study used social media comment data to build a comprehensive framework. It covers performance, brands, health, and content. This offers a new perspective on VR user needs research.

Additionally, this study examined Bilibili users' subculture context. It revealed links between technology acceptance of local brands like Huawei and Xiaomi and cultural preferences. This expands the theoretical boundaries of technology diffusion. It provides theoretical support for VR product localization strategies in a global context.

3. Limitations and Future Research

This study has several limitations. First, it remains uncertain whether commenters are actual users; some opinions may come from non-users, potentially affecting the validity of the findings. Future research could incorporate user behavior data or verification mechanisms to improve data reliability.

Second, the study does not distinguish between different types of VR devices. Differences in form factor—such as HMD and Glass—may lead to significantly varied user experiences. It is recommended that future studies segment device types and conduct separate modeling accordingly.

Third, the analysis lacks a dynamic perspective on evolving user needs. Given the rapid pace of technological advancement, longitudinal research is needed to capture shifts in consumer expectations, particularly as innovations like the metaverse reshape the VR landscape.

Fourth, this study focuses on the cultural context of Chinese ACG communities. Future research should explore cross-cultural differences by comparing users from diverse backgrounds, such as Europe, America, and Asia. markets, to better understand global variations in VR adoption and preferences.

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Authors

Ji Yang Received the B.A. degree in Management from HuangHuai University, China, in 2013, M.A. degree in Management from Zhongyuan University of Technology, China, in 2016, respectively.

Mr. Yang joined the faculty of the Global Business at Kyonggi University, Suwon, Korea, in 2023. He is currently a doctoral student in global business. Kyonggi University. He is interested in Quality Management, E-business etc.

Zhi-Zhong Xiao Received the B.A. degree in Traffic Engineering from North China University of Water Resources and Electric Power, China, in 2012, M.A. degree in Traffic Engineering Jiaotong University,

respectively. from China, Chongqing in 2016, respectively. Mr. Xiao joined the faculty of the Department of Global Business at Kyonggi University, Suwon, Korea, in 2023. He is currently a doctoral student in global business. Kyonggi University. He is interested in Management Information Systems, E-business etc.

Zi-Yang Liu Received the B.A. degree in Management from Army superintend institute of shijiazhuang China PLA ,China, in 2006, M.A. degree and Ph.D. degree in Management from Kyonggi University,

Korea, in 2010 and 2013, respectively. Dr. Liu joined the faculty of the Global Business Kyongggi University, Korea in 2015. He is currently a professor of Global Business at Kgonggi University. He is interested in Quality Management. Management Information Systems, International economics, E-business etc.