User Information Behavior in Virtual Reality Environments: Research Developments and Trend Analysis (Postprint)

Authors: Wang Xiwei, Li Yueqi, Wang Duo, Wei Yanan

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Abstract

[Purpose/Significance] Through the collection and analysis of foreign literature on user information behavior in virtual reality environments, this study aims to understand the research progress and future trends of virtual reality technology applications, providing reference and inspiration for research on virtual reality technology in the field of library and information science. [Method/Process] Using literature analysis and knowledge graph visualization methods, this study analyzes and visually presents the research hotspots and trends of virtual reality technology abroad. [Results/Conclusion] The research hotspots in foreign literature on user information behavior in virtual reality environments are mainly distributed in studies on user information acceptance behavior, user adoption behavior, and human-computer interaction behavior in virtual reality environments. Future development trends in user information behavior research in virtual reality environments will focus more on three aspects: user social behavior in virtual reality environments, multi-domain user adoption behavior in virtual reality environments, and user reading behavior in virtual reality environments.

Full Text

Research on the Development and Trends of User Information Behavior in Virtual Reality Environment

Wang Xiwei[1],[2], **Li Yueqi**[1], **Wang Duo**[1], **Wei Yanan**[1] [1]School of Management, Jilin University, Changchun 130022 [2]Big Data Management Research Center, Jilin University, Changchun 130022

Abstract: [Purpose/Significance] This paper collects and analyzes relevant foreign literature on user information behavior in virtual reality environments to understand the research progress and future trends of virtual reality technology applications, providing reference and inspiration for VR-related research in the

field of library and information science. [Method/Process] Using literature analysis and knowledge mapping visualization methods, this study analyzes and visually presents research hotspots and trends in foreign virtual reality technology. [Result/Conclusion] Research hotspots in foreign literature on user information behavior in virtual reality environments are mainly distributed across three areas: user information acceptance behavior, user adoption behavior, and human-computer interaction behavior in VR environments. Future research trends will focus more on three aspects: user social behavior in VR environments, multi-domain user adoption behavior in VR environments, and user reading behavior in VR environments.

Keywords: virtual reality; user; information behavior; research hotspot **Classification Number:** G203 **DOI:** 10.13266/j.issn.0252-3116.2020.05.002

The Ministry of Industry and Information Technology has pointed out that the global virtual reality industry is transitioning from its initial cultivation phase to a rapid development period in 2019, emphasizing that China' s VR industry chain will be basically established by 2020 and its overall strength will rank among the world' s top by 2025 [1]. Virtual reality (VR) uses computer simulation to create a three-dimensional virtual world, providing users with sensory simulations of vision, hearing, touch, and more, creating an immersive experience [2]. Through interactive devices such as head-mounted displays and controllers, users can perform real-time information input and output behaviors [3]. With technological improvements and policy support, VR applications are gradually maturing, particularly in computer science, education, and behavioral studies where applications and research results are abundant. Research on user information behavior in virtual reality environments has become a hot topic in human-computer interaction studies in both academia and industry in recent years.

However, what specific information behaviors do users exhibit in VR environments, and how do these differ from information behaviors in traditional environments? Research in this area holds significant value for improving user experience and enhancing innovative information service models in library and information science under the backdrop of VR human-computer interaction technology development.

This study attempts to address three issues: to review and analyze the origin and current development status of research on user information behavior in VR environments; to summarize research hotspots in this field in recent years; and to analyze development trends using knowledge mapping tools. Through literature review and analysis, this paper uses knowledge mapping tools to visually analyze research hotspots and trends, aiming to provide reference for future VR-related research in domestic library and information science.

2 Sample Selection

Currently, most foreign research on user information behavior in VR environments adopts experimental methods to compare and analyze the impact of VR environments versus traditional environments on user behavior, examining whether VR environments have positive effects on specific behaviors such as learning, reading, and touring. However, relatively few studies analyze the specific information behaviors that users exhibit in VR environments.

To ensure comprehensive and inclusive literature samples, we selected the Web of Science (WoS) database (including SCI and SSCI) due to its high-quality literature and advantageous coverage. We retrieved literature published between January 1, 1998 and December 31, 2018 (a 20-year span) as our analysis sample.

Based on relevant literature [4] and expert consultation, we determined search terms covering research themes including virtual reality, behavior, interaction, and user study. The final search query was: TI=("virtual reality") AND TS=(user OR behavior OR "seek" *OR" interact*" OR adoption OR acquisition), yielding 1,824 results. After limiting to peer-reviewed journals, we obtained 458 documents covering computer science, psychology, education, economics and management, and other disciplines.

Among these, 59 key documents were selected for content and hotspot analysis through manual screening. The screening process involved: limiting document types to exclude reviews and conference papers from the 458 retrieved documents; having two research teams manually filter out literature unrelated to our review topic, such as studies focusing on VR technology application and design rather than information behavior; and having three domain experts review and validate the screening results, finalizing 59 key documents for analysis (see Figure 1 [Figure 1: see original paper]).

3 Origins and Development of VR User Information Behavior Research

Through summarizing foreign literature on user information behavior in VR environments and plotting a timeline with years on the horizontal axis and document counts on the vertical axis (see Figure 2 [Figure 2: see original paper]), we can understand the origin, development, and current state of this research domain, guiding scholars to better track its dynamics and trends.

3.1 Initial Stage (1999-2005)

From both literature volume and content perspectives, research on user behavior in VR environments between 1999-2005 was in its initial stage. Studies focused on initial VR user interface design, hardware devices, interaction technologies, and content selection. Representative research includes: using Norman' s action model to measure VR user interface effectiveness across three dimensions —target task completion, virtual world exploration behavior, and user-system

interaction degree [5]; and evaluating alternative VR system configurations combining different hardware and interaction technologies through user experience and preferences [6]. In assisting user information comprehension, scholars proposed that virtual environments could stimulate user imagination and help users construct knowledge processes by increasing information observation perspectives [7], while others found that real-time interactive mechanical model systems could train users' assembly and disassembly skills for flexible parts [8].

3.2 Development Stage (2005-2015)

Between 2005-2015, foreign research on VR user information behavior entered a development stage. While literature growth was slow, the increase was significant compared to the initial stage, with studies beginning to examine user adoption behavior toward VR systems. Scholars found that compared to ordinary shopping centers, VR shopping mall interfaces positively impacted customer satisfaction, enhancing shopping experiences through convenience, enjoyment, and product quality assurance [9]. VR environments also provided possibilities for product display and testing, evoking positive emotional connections during shopping and promoting consumer behavior [10]. Other studies evaluated the effectiveness and feasibility of VR participatory design systems by comparing user interactions with real versus virtual products [11]. As VR technology matured, interface design research shifted toward human-computer interaction methods, examining the impact of free versus constrained speech input on user interaction experience [12]. After introducing VR into remote operation scenarios, researchers found that VR-based multimodal remote operation interfaces offered stronger adaptability and intuitiveness compared to other interfaces [13].

3.3 Rapid Growth Stage (2015-Present)

Since 2015, literature on VR user information behavior has grown rapidly, indicating the field has entered a rapid development phase. Research has become more in-depth, focusing primarily on: user information acceptance behavior in VR environments, comparing information acceptance effects between virtual and traditional environments [14-15] and identifying factors affecting information acceptance effectiveness [16-17]; user technology acceptance behavior toward VR technology, systems, and platforms, constructing extended technology acceptance models that incorporate factors such as perceived entertainment [28], user characteristics [30], immersion experience [31], interactivity [36], and perceived usefulness [38] to study their impact on user adoption behavior and satisfaction; and since 2019, VR technology has been introduced into economics and management research to analyze how enhanced interactivity in VR shopping systems promotes user decision-making [52] and influences purchase, usage, and switching behaviors [53]. Scholars have also increasingly focused on human-computer interaction behavior in VR environments, optimizing interaction modes by introducing multimodal channels such as gestures [39], olfaction, and touch [41] to enhance environmental realism and improve user experience.

Recently, researchers have proposed user-editable VR interaction platforms. As relevant literature continues to grow and research directions become clearer, reviewing user information behavior studies helps researchers understand current hotspots and future directions.

4 Analysis of Research Hotspots

4.1 Key Journals and Literature

According to WoS classification, research on user information behavior in VR environments concentrates in computer science (60%), psychology (20%), and economics/management and education (10% each). According to the American Society for Information Science and Technology's definition, information science is a multidisciplinary field using computer science, cognitive science, psychology, systems science, and other foundational knowledge to solve information problems [14]. Research on user information behavior in VR environments similarly requires cognitive psychology to analyze user cognition, comprehension, acceptance, and psychological suggestion of information, and computer science to optimize interaction methods between users and VR systems.

Table 1 shows the main journals and key literature on VR user information behavior research after manual screening. As evident from the table, publications in this area are increasing, particularly in the last three years, focusing on user information acceptance and learning effects in VR environments, user intentions to use VR systems, satisfaction and user experience, and human-computer interaction methods in VR.

4.2 Keyword Clustering Knowledge Map Analysis

To analyze research themes, we used CiteSpace for keyword clustering analysis of foreign VR user information behavior research in the past five years, generating a thematic clustering map (see Figure 4 [Figure 4: see original paper]). After filtering irrelevant terms, clusters emerged around: VR environment, VR experience, VR technology acceptance model, panoramic display, and VR technology usage.

The "virtual reality environment" cluster includes keywords such as simulation, game, impact, education, validation, sense, model, presence, and information, focusing on VR environment's impact on users, information acceptance effectiveness, and presence experience. The "virtual reality experience" cluster includes involvement, immersion, telepresence, and information technology, focusing on user experience, immersion, and engagement in VR environments. The "virtual reality acceptance model" cluster includes customer satisfaction and technology acceptance model, focusing on user technology acceptance models and satisfaction in VR environments. The "panorama manifestation" cluster includes human-computer interaction, designed mounted display, and system, focusing on human-computer interaction and panoramic information display methods in

VR. The "using virtual reality technology" cluster includes immersive, sex difference, and gender difference, focusing on factors influencing VR technology usage. Based on these clusters, foreign VR user information behavior research hotspots can be categorized into three areas: user information acceptance behavior, user adoption behavior, and human-computer interaction behavior.

4.3 Thematic Analysis of Research Hotspots

4.3.1 User Information Acceptance Behavior in VR Environments Information acceptance is a bidirectional constructive cognitive activity reflecting the relationship between information objects and subjects, representing a coupling relationship between the receiving subject' s context and the information object' s context [15], emphasizing users' willingness and behavior to accept information in specific information environments. Due to its panoramic and interactive information presentation, VR environments provide a setting where users can conceptualize and materialize abstract information, thereby changing their information acceptance level. Current research on user information acceptance behavior in VR environments focuses on information acceptance effectiveness in education and three-dimensional visualization of information resources.

In information acceptance effectiveness studies, most compare VR information acceptance effects with traditional methods, finding both promoting and inhibiting effects. VR environments enhance user perception [16], increase information observation perspectives [17], and dynamically deconstruct abstract scientific phenomena to deepen understanding and acceptance of objective reactions or complex knowledge structures [18]. Scene experiences enhance user empathy through immersion, promoting understanding and strengthening identification [19]. In practical operations, interactive processes deepen users' familiarity with industrial skills [22]. However, VR environments may also hinder information acceptance. Multimedia learning cognitive theory suggests that complex visual materials may impede information acceptance [20]; users may experience cognitive load with higher task complexity and difficulty requiring additional cognitive resources [21]; composite multimodal feedback presentation may cause information overload, leading to confusion and distraction [22], with phenomena of improved operational skills but poorer theoretical acceptance [23].

In three-dimensional visualization of information resources, scholars have long proposed introducing VR technology into libraries and museums for 3D visualization of information resources [24]. VR technology addresses the lack of interactivity in digital and mobile libraries. Applications in libraries and museums concentrate on: virtual scene construction research, where users can immerse themselves in panoramic virtual libraries to perform book retrieval and reading behaviors [25]; designing VR libraries for specific user groups helps improve information acquisition efficiency based on user characteristics [26]; and virtual device usage research. EON, a VR software provider [27], offers interactive online libraries allowing librarians, educators, and students to combine 3D information content with video, audio, and annotations on mobile devices.

Studies show that reading time in VR environments exceeds that in traditional desktop environments without affecting reading comprehension [28].

4.3.2 User Adoption Behavior in VR Environments User adoption behavior focuses on users' subjective adoption and usage of VR technology, interaction methods, and applications from their perspective, forming the basis for usage [32], continued use [33], and switching behaviors. Research on user adoption behavior in VR environments primarily concentrates on users' adoption of VR technology, mostly employing technology acceptance models to analyze adoption behavior from user experience and satisfaction perspectives.

Scholars believe virtual tours can promote users' intentions to visit destinations and hotels, with virtual previews generating more positive psychological intentions and stronger presence than image previews, thereby enhancing brand experiences and promoting usage behavior [29]. Enhanced immersion and entertainment stimulate curiosity, promoting tourism intentions [30]. VR technology strengthens user engagement, scene effectiveness, vividness, entertainment, and sense of control to enhance presence, improve user experience, and stimulate subsequent adoption intentions [31-32]. Compared to 2D video, virtual video amplifies immersion through enhanced vividness and interactivity, positively influencing satisfaction with virtual viewing behavior [33]. Perceived entertainment, user motivation, emotional inspiration [34], and user characteristics are key variables affecting VR experience quality, presence, and immersion, with mediating variables such as social interaction and social connection [36] indirectly influencing VR user adoption behavior.

4.3.3 Human-Computer Interaction Research in VR Environments Human-computer interaction is the information exchange process between humans and computers to complete tasks [37], evolving into interactions between users and information systems, intelligent machines, and devices. VR human-computer interaction research focuses on interaction interface design, user interaction method optimization, and factors influencing interaction experience.

VR user interface design emphasizes friendliness, usability, and effectiveness. Scholars have evaluated VR interface usability by comparing user interactions with real versus virtual products [38]. Comparing mouse, controller, and gesture interfaces revealed that gesture interaction facilitates visualization tasks and 3D graphics construction, with users experiencing greater entertainment [39].

In optimizing interaction methods, gesture interaction devices have pioneered multimodal human-computer interaction research to improve experience. Studies comparing "audio-visual" and "visual-haptic" interaction combinations found users prefer audio-visual experiences, as auditory interaction provides stronger engagement and immersion [40]. Olfactory and tactile interactions can also improve mood and presence; enhanced tactile stimulation increases presence and relaxation, while olfactory interaction has less emotional impact [41]. Head-mounted displays affect users' sound localization performance, with added vi-

sual information, virtual hand positions, and room dimensions improving sound localization [42]. Compared to real environments, virtual environments are auditorily impoverished; introducing "user attention-driven gaze-audio enhancement technology" can increase realism and promote effective interaction [43]. Comparing auditory, haptic, and visual cues' impact on presence found that auditory and haptic cues significantly affect task performance and user experience. Adding multimodal information content may compromise environmental fidelity but improves usability and overall experience [44].

In studying factors affecting human-computer interaction experience, presence is an important dimension for understanding interaction behavior. However, presence definitions and measurement methods vary across domains. Scholars have designed and validated a multimodal presence measurement scale for VR environments using a "physical-social-self presence" three-dimensional theory [45]. Visual delay in motion is also a crucial factor affecting subjective interaction experience; comparing user tracking tasks under no-delay versus delay conditions found that users gradually adapt to delay frequencies, with experience gradually recovering [46].

5 Future Research Trends of User Information Behavior in VR Environments

Using CiteSpace to map trends from 2014-2019 (see Figure 5 [Figure 5: see original paper]), nodes represent hotspot keywords over time, with node size indicating research frequency. Development trends show foreign research gradually shifting focus from VR technology and environment design to user behavior and perception in VR environments, emphasizing optimization of information visualization methods and VR systems' function in promoting user information comprehension in educational contexts. Recent research focuses on using models to study the impact of user behavior, presence, and immersion on user experience, eventually developing toward VR services, user adoption of VR systems, and social behavior in VR environments. Overall, future research trends include:

5.1 User Social Behavior Research in VR Environments

Building upon human-computer interaction research, scholars are increasingly focusing on how social interaction and social connections in virtual environments affect user experience. Studies show social interaction influences user experience, with social connections enhancing immersion and positively moderating satisfaction and system loyalty [47]. Perceived conversational distance and avatar communication in VR provide positive psychological cues, promoting social behavior [48]. By analyzing user behavior characteristics, VR scene impacts on social experience, and ethical and privacy issues in VR social platforms, researchers propose effective interaction scene construction methods to optimize VR social platform design [49]. Additionally, mobile VR social platforms have

been constructed to analyze performance and identify potential bottlenecks [50]. Future VR social platforms may also test users'social abilities in specific contexts [51].

Future research will focus on promoting mobile VR social platforms and investigating user continuous usage and adoption behaviors. Scholars propose integrating eye-tracking technology to track user browsing behavior, pushing product reviews and recommendations based on gaze focus to promote purchase behavior [55], enabling new forms of intelligent social interaction.

5.2 Multi-Domain User Adoption Behavior Research in VR Environments

According to key journal and literature statistics, 2019 saw continued growth in VR user adoption behavior research, with focus shifting from VR technology and tour system adoption to e-commerce decision-making promotion research.

Studies show that user-product interaction in virtual scenes positively influences decision-making, leading to approach or avoidance behaviors (intentions to stay, purchase, or not) [52]. Variables such as presence, brand representation [53], emotional cues, and external stimuli [54] enhance interaction effectiveness in VR shopping environments, changing user attitudes, satisfaction, and loyalty toward virtual shopping systems, thereby increasing purchase intentions and promoting usage. Scholars propose using multi-technology integration, such as introducing eye-tracking to VR environments to track browsing behavior and provide real-time product recommendations.

Current adoption research mostly focuses on how environment and content affect user experience and satisfaction. Future cross-hardware and cross-domain comparative experiments will increase. Although users have basically adopted virtual shopping models, user numbers remain small and information processing is still in the experience stage. Future research will examine how users process and adopt system-pushed information. When VR systems achieve mass adoption, more externally valid conclusions will emerge, with longitudinal studies determining whether adoption behaviors are temporary or persistent.

5.3 User Reading Behavior Research in VR Environments

VR' s panoramic display function enables 3D visualization of library and museum information resources, providing a new paradigm for digital reading service transformation. VR reading achieves real-time interactive reading based on immersive visualization, enhancing reading immersion and improving reading experience, becoming an emerging research hotspot [56].

Scholars propose that VR reading time exceeds traditional desktop reading without affecting comprehension [28]. VR is widely applied in foreign university libraries, focusing on VR scene construction, digital resource visualization, and library location navigation [57]. Installing apps or clients on mobile devices

enables 3D visualization for real-time reading and book location navigation, achieving classic preservation and human resource optimization. Domestic libraries have also begun using VR for scene reproduction and roaming services, attempting to build 3D information resources and implement somatosensory capture [58] and gesture interaction reading modes [59].

Based on current developments, future VR applications in user reading behavior research will focus more on 3D visualization of information content, construction of mobile personal libraries, and implementing user-preferred library designs using VR headsets. As VR technology matures in libraries, scholars can pay more attention to unique patterns and influencing factors of user reading behavior in VR environments.

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Note: Figure translations are in progress. See original paper for figures.