From Passive Reception to Active Participation: Empowering Non-Professionals in Interior Design Co-Creation through Virtual Reality-A Case Study of Residential Spaces

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Abstract: The increasing professionalization of interior design has created a significant communication barrier between designers and their non-professional clients. Virtual Reality (VR) technology, with its immersive and interactive features, offers a potential solution to bridge this gap. However, current research primarily focuses on optimizing VR as a tool for designers. Using residential design as a case study, this paper discusses the current state of VR-assisted interior design. Through questionnaire surveys, it investigates which elements of VR most significantly impact user experience and examines whether VR technology can transform users from passive recipients into active participants in the co-creative process. The findings aim to provide a new direction for the application of VR in the field of interior design.

Keywords: Technological Innovation; Interior Design; Virtual Reality Technology; Application Prospects

1. Introduction

The field of interior design has evolved significantly to date, progressing from exploratory pure decoration to the establishment of systematic theoretical frameworks, and from manual paper drafting to the use of specialized software such as CAD. As technologies have become increasingly specialized, interior design has matured as an academic discipline. However, this professionalization has inevitably led to information disparities between designers and clients. For instance, the average resident may lack proficiency in reading drawings or using design software, and may have an insufficient understanding of current safety standards. As a result, users often struggle to communicate effectively with designers or engage deeply in the design process. Nevertheless, driven by technological advancements and social trends, virtual technologies such as VR have been integrated into architectural design. With their powerful three-dimensional visual representation and high Immersion, these technologies can help designers and clients communicate requirements in a visualized manner.

Current research on VR-assisted interior design remains relatively narrow in perspective, focusing primarily on "optimizing VR design tools under the leadership of designers." Studies often analyze the existing applications and potential future developments of VR technology in interior design, with specific emphasis on how to assist designers in utilizing VR or advocating for its integration into educational settings to support teaching and learning. In contrast, there has been limited attention given to non-professional users operating VR devices, and a lack of user-centric demand analysis during the design process.

2. Overview and Application Status Analysis of VR Technology

2.1 Overview of VR Characteristics

Virtual Reality (VR), is a comprehensive practical technology developed in the 20th century. It utilizes computer technology to simulate a virtual three-dimensional world, allowing users to enter this digital environment and interact with it using specific equipment such as VR headsets. This provides users with a uniquely immersive experience.

Currently, VR technology primarily focuses on three aspects: the design of virtual environments, the sensation of human-computer interaction, and the simulation of physical effects. For instance, if a designer uses 3D design software (e.g., 3D Max) to create a virtually observable dynamic environment, and a user accesses this space using VR equipment, they should not only gain visual perception but also multi-sensory perceptions such as auditory, olfactory, and gustatory experiences. If the user performs actions that affect the physical environment, both the user

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and the environment can perceive the outcomes of these actions.

These technological capabilities endow VR with three key characteristics: Immersion, Conceptualization, and Interactivity[1]. From the perspective of Immersion, specific technological methods enhance human perception of the virtual world. Currently, VR technology is more advanced in delivering visual and auditory experiences. Users can view the virtual world from different angles and discern their orientation within the virtual space through variations in sound intensity, collectively creating a sense of "being there."

From the perspective of Conceptualization, VR enables the replication of real-world objects while also allowing the creation of entities that defy conventional reality. Users can freely bring imaginative concepts to life, translating unrealistic ideas from their minds into the virtual world.

From the perspective of Interactivity, users can not only dynamically observe the virtual world through VR headsets but also utilize specialized controllers or gloves that translate hand gestures into actions within the virtual environment. This facilitates interaction and provides users with feedback, enhancing their sense of presence within the digital realm.

2.2 Current Status of VR-Assisted Interior Design

The interior design process can be divided into three stages: first, the user confirms the desired spatial functional layout with the designer; second, the user specifies interior design preferences or styles, and the designer initiates the design using specialized software; third, after the designer completes the preliminary design, both parties review and communicate adjustments to finalize the design outcome[2]. Although this approach generally meets user requirements, several common issues persist. For example, throughout the design process, users often lack the professional knowledge to fully comprehend spatial arrangements presented in drawings. If non-professional users attempt to learn design software independently, they face significant challenges and time investments. Additionally, misunderstandings may arise during offline purchases due to unfamiliarity with technical terminology. In some cases, while discussions with designers regarding renderings proceed smoothly, the final renovation results may substantially differ from the initial visualizations.

The integration of VR technology offers more intuitive and realistic visualizations, while its gamified operation lowers the barrier to entry[3]. Image-based and realistic simulation capabilities facilitate communication between users and designers, allowing users to bypass specialized knowledge gaps and effectively mitigate communication barriers. For instance, IKEA's 2022 launch of IKEA Kreativ utilizes LiDAR scanning to create accurate 3D replicas of rooms. Users can select furniture from IKEA's catalog, customize colors and dimensions, and drag items directly from the library into the virtual space for adjustment. Notably, the platform incorporates collision feedback between furniture and the 3D environment, enhancing the realism of the design experience. Through this platform, users gain clear access to product information and purchasing channels while better visualizing furniture scale and layout according to personal preferences. However, the platform currently supports only three view modes—axonometric, top-down, and side views—limiting dynamic observation capabilities. While sacrificing some viewing freedom, it offers greater flexibility in furniture selection and arrangement compared to conventional VR viewing systems.

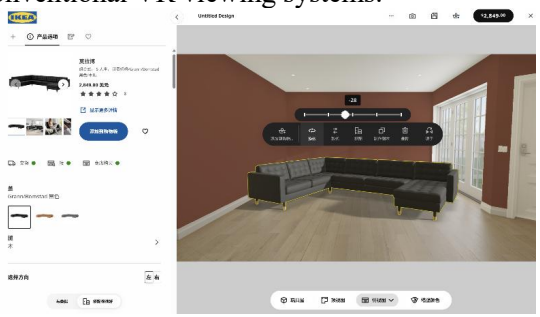

Figure 1. IKEA Kreativ's Operating Interface[4]

Meanwhile, compared to other industries, the development and application of VR technology in the field of interior design remains relatively immature. Firstly, the cost of acquiring VR equipment is substantial, and pursuing higher-quality equipment inevitably leads to further increased expenses. Moreover, if design firms invest in VR systems, they must allocate additional resources to train employees in VR-related skills. Non-professional clients may also encounter difficulties when reviewing design outcomes due to unfamiliarity with VR operation, among other challenges, highlighting the issue of high implementation costs[5].

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Secondly, beyond experiencing VR environments through preset lens distances on mobile devices (e.g., smartphones), mainstream VR equipment currently consists primarily of head-mounted displays and all-in-one VR systems[6]. The former places significant strain on the user's cervical spine, making prolonged use inadvisable, while the latter typically requires wired connections that may restrict movement and pose tripping hazards during operation. Both types of equipment carry inherent limitations regarding user safety and convenience.

Finally, individual physiological factors may impede effective utilization of VR technology. Users with pre-existing ocular conditions or susceptibility to motion sickness may experience discomfort or adverse effects, preventing them from fully benefiting from VR-assisted design processes. These user-specific variations represent significant challenges to universal implementation[7].

3. Research Methodology and Data Analysis

3.1 Research Methodology and Questionnaire Design

This study employs a questionnaire survey methodology to identify the key factors most significantly influencing user immersion in contemporary VR design [8]. The questionnaire comprised four sections: the first gathered participants' basic information (such as occupation and age); the second assessed their fundamental understanding of VR technology; the third investigated their history of using VR equipment and overall experience; the fourth section featured questions based on literature review, examining the application advantages and existing limitations of VR technology in interior design, to gauge participants' specific perceptions and evaluations of integrating VR technology into home decoration design.

During the data collection phase, this study implemented a randomised sampling survey via an online platform, distributing 202 questionnaires. After excluding invalid responses, 189 valid questionnaires were recovered, yielding an effective response rate of 94%. The average completion time for all valid questionnaires was approximately 75 seconds. Data collection concluded on 4th September.

3.2 Descriptive Statistical Analysis

3.2.1 Basic information of participants

As shown in Table 1， among the participants in the questionnaire survey, the majority were aged between 18 and 35, accounting for 82.01%, indicating a high level of acceptance of VR technology among young and middle-aged groups. In terms of occupational distribution, salaried employees constituted 42.33%, freelancers accounted for 11.64%, and professionals in design/architecture-related fields represented 3.70%. Collectively, employed individuals comprised 57.56% of the respondents, demonstrating that engagement with VR technology requires a certain income threshold.

Table 1. Age and Occupation of Participants

Question	*Options*	*Frequency*	*Percentage (%)*
What is your age?	Below 18	3	1.59
	18-25	102	53.97
	26-35	53	28.04
	36-45	17	8.99
	46 and above	14	7.41
What is your current occupation?	Student	76	40.21
	Salaried employee	80	42.33
	Freelancer	22	11.64
	Design/Architecture professional	7	3.70
	Prefer not to say	3	1.59
	Other	1	0.53
Total		189	100.0

3.2.2 Participants' Experience with VR Equipment

In Table 2, among the participants in the survey, 18.52% reported owning a personal VR device, while 57.67% had no device but had experienced VR projects. In total, 76.19% of respondents had used VR equipment. Among those who had used VR devices, 74.31% had participated in commercial VR projects, followed by 45.83% who had used VR in schools or educational institutions. These results indicate that VR devices have not yet been widely adopted among the general population, though most individuals possess a basic understanding of VR technology and its fundamental operational procedures.

Table 2. Situations where Participants Use VR

Question	*Options*	*Frequency*	*Percentage (%)*
Do you own or have you ever used a VR device?	Yes, I own a VR device	35	18.52
	No, but I have experienced VR devices	109	57.67
	No, never used	45	23.81
Commercial	Not selected	37	25.69

project in mall/experience store (n=144)	Selected	107	74.31
School/educational institution (n=144)	Not selected	78	54.17
	Selected	66	45.83
Workplace (n=144)	Not selected	119	82.64
	Selected	25	17.36
Other (n=144)	Not selected	143	99.31
	Selected	1	0.69
Total		189	100.0

3.2.3 Participants' VR Experience Feedback

According to the voting results from the survey participants in Table 3, device comfort was prioritized as the highest factor affecting the VR experience, followed by interaction fluency ranking second. Content design and scene realism were ranked third, while sound effects and atmosphere creation placed fourth.

Table 3. Factors Influencing Immersion as Perceived by Participants

Options	*Sample Size*	*Mean*	*Standard Deviation*
Interaction Latency	189	0.651	0.478
Device Comfort	189	0.810	0.394
Content Design & Scene Realism	189	0.598	0.492
Sound Effects & Atmosphere	189	0.386	0.488
Other	189	0.005	0.073

Table 4 shows that a total of 68.25% of participants were deeply impressed by the enhanced spatial awareness, while 62.43% found the free interaction within the virtual environment particularly notable. In this table,only 34.92% of respondents viewed VR as a tool for creative expression, indicating that VR technology remains underdeveloped in this aspect.

Table 4. Participants' Most Impressive Aspects of VR

Question	*Options*	*Frequency*	*Percentage (%)*
Free Interaction	Not selected	71	37.57
	Selected	118	62.43
Enhanced Spatial Awareness	Not selected	60	31.75
	Selected	129	68.25
As a Tool for Creative Expression	Not selected	123	65.08
	Selected	66	34.92
Other	Not selected	188	99.47
	Selected	1	0.53
Total		189	100.0

3.2.4 Application of Home Design and VR Technology

In Table 5, among the participants in the survey, 47.62% reported having used VR technology during home renovation or furnishing processes, indicating that the adoption of VR in the interior design industry remains relatively limited. Among those who had experienced VR in interior design contexts, 75.56% were particularly impressed by the ability to intuitively perceive spatial dimensions and proportions, followed by 68.89% who highlighted the value of freely adjusting furniture layouts to optimize space utilization. However, 65.56% of these participants did not find collaborative design and communication with designers or family members facilitated by VR to be noteworthy, suggesting that communication barriers between designers and non-professional users remain prevalent.

Based on participant feedback, the factors currently exerting the greatest impact on immersion in VR design are as follows: first, the operational difficulty of VR equipment; second, the comfort of wearing and using VR devices; third, the fluency and clarity of the in-scene visuals; and fourth, the degree of interaction freedom.

Table 5. Participants' Perspectives on VR-Based Home Design

Question	*Options*	*Frequency*	*Percentage (%)*
Have you ever used VR technology during home renovation or furnishing?	Yes	90	47.62
	No	99	52.38
Free adjustment of furniture layouts to optimize space utilization (n=90)	Not selected	28	31.11
	Selected	62	68.89
Intuitive perception of spatial dimensions and proportions (n=90)	Not selected	22	24.44
	Selected	68	75.56
Collaborative design and communication with designers/family members (n=90)	Not selected	59	65.56
	Selected	31	34.44
Other (n=90)	Not selected	90	100.00
Total		189	100.0

4. Conclusion

This study explores the application of VR technology in interior design, offering novel solutions for non-professionals to engage in the design process. Findings indicate that VR technology, through its immersive experience and real-time interactive capabilities, significantly lowers the barriers to spatial comprehension and design communication. It

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transforms abstract concepts into tangible, experiential virtual environments, thereby enhancing collaborative efficiency and consensus-building between users and designers.

However, this study also identifies notable limitations in current VR technology's capacity to support non-professionals' deep involvement in design. On one hand, VR design tools remain insufficiently adapted to mass-market demands in terms of cost, accessibility, and user-friendliness. On the other, the research primarily relies on questionnaire analysis from random sampling, lacking comparative testing with physical VR equipment. Furthermore, the sample's coverage and representativeness exhibit certain constraints, potentially affecting the comprehensiveness of findings.

Consequently, future research should deepen in the following directions: firstly, developing more lightweight and intelligent VR-assisted design systems, such as integrating AI generative design capabilities to accommodate user personalisation needs; secondly, conducting more targeted empirical studies with expanded sample sizes, employing advanced VR equipment to conduct comparative experiments on the design capabilities of professionals versus non-professionals, systematically evaluating the technology's actual impact on design participation, scheme satisfaction, and design efficiency. Overall, the value of VR technology in interior design lies not merely in enhanced visual presentation, but in establishing a seamless communication and collaborative design platform. This facilitates a genuine opening of the design process to users, returning it to a user-centric foundation.

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