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ORIGINAL

# Construction of user experience model inilmmersive virtual environment based on ontology

## Construcción de un modelo de experiencia de usuario en entorno virtual inmersivo basado en ontología

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## ABSTRACT

With the rapid development of virtual immersion technology, immersive virtual environment (IVE) has shown its unique application potential in many fields. The purpose of this study is to explore and construct a user experience model in immersive virtual environment based on ontological theory. The key factors affecting user experience include sensory experience, interaction control, distraction factors, realism perception, ownership, motion control and location. Environmental dimension and physical dimension are the two core aspects of user experience. Sensory experience and sense of ownership have a significant positive impact on users' sense of existence in a specific environment, while control dimension, sensory dimension and realism dimension play an important role in enhancing users' sense of ontology. The different dimensions of the sense of ontology have a significant positive impact on the user's sense of immersion and presence, which verifies the central role of the sense of ontology in enhancing the user's immersion experience. We look forward to further enhancing the user's immersion experience and promoting the application of immersive virtual environment in a wider range of fields.

**Keywords:** Ontology; Immersive Virtual Environment; Presence; User Experience.

## RESUMEN

Con el rápido desarrollo de la tecnología de inmersión virtual, immersive virtual environment (IVE) ha demostrado su potencial de aplicación único en muchos campos. El propósito de este estudio es explorar y construir un modelo de experiencia de usuario en un entorno virtual inmersivo basado en la teoría ontológica. Los factores clave que afectan la experiencia del usuario incluyen la experiencia sensorial, el control de la interacción, los factores de distracción, la percepción del realismo, la propiedad, el control del movimiento y la ubicación. La dimensión ambiental y la dimensión física son los dos aspectos centrales de la experiencia del usuario. La experiencia sensorial y el sentido de propiedad tienen un impacto positivo significativo en el sentido de existencia de los usuarios en un entorno específico, mientras que la dimensión de control, la dimensión sensorial y la dimensión del realismo juegan un papel importante en la mejora del sentido de ontode los usuarios. Las diferentes dimensiones del sentido de la ontotienen un impacto positivo significativo en el sentido de inmersión y presencia del usuario, lo que verifica el papel central del sentido de la ontoen la mejora de la experiencia de inmersión del usuario. Esperamos mejorar aún más la experiencia de inmersión del usuario y promover la aplicación de un entorno virtual inmersivo en una gama más amplia de campos.

**Palabras clave:** Ontología; Entorno Virtual Inmersivo; Presencia; Experiencia del Usuario.

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## INTRODUCTION

As virtual immersion experiences become more prevalent and user experience research deepens, the conceptualization of immersive virtual environments is undergoing a transformation. This shift acknowledges that a user's presence in the virtual realm encompasses more than just a digital facade; it is an intricate interplay of their physical self and their virtual avatar.[1,2] This perspective is grounded in existential philosophy, which underscores the pivotal function of ontology in bridging the gap between the tangible and the digital realms.[3] Research indicates that bolstering the perception of ontology not only heightens users' immersion but also positively influences their performance and emotional responses within virtual settings.[4,5]

Based on the ontology theory, this paper explores the related factors that affect the sense of presence in user experience in immersive virtual environment and derives the model, and derives the structural equation model by using literature analysis, questionnaire survey and variance analysis. The conclusion shows that in immersive virtual environment, user experience is influenced by the interaction of the complex constructed by physical entities and virtual environment, and the user experience model can help practitioners better understand the user experience in a specific environment, and then carry out relevant design and research work.[6]

## METHOD

### Immersive Virtual Environment

Digitally crafted realms that offer users deep involvement and a high degree of realism allow them to extend their actual presence into digital realms.[7] Individuals can engage with these environments in real-time, fostering a feeling of being there and establishing connections with the virtual surroundings and other participants [Kay Kyeongju Seo]. Immersive virtual environments (IVEs) are often constructed using a combination of immersive technologies such as AR, VR, and MR, and they leverage sophisticated hardware like head-mounted displays (HMDs) and motion-tracked gloves, along with software like game engines (Unity, Unreal Engine), to deliver an intensely immersive and interactive user experience.[8] Studies by Bob G. Witmer and Michael J. Singer from 1998 have determined that the success of immersive virtual environments (IVEs) is largely associated with the level of presence users report feeling within these environments. This includes dimensions of control, sensory input, distraction, and the perception of reality.[9]

### Sense of Body

The concept of Sense of Embodiment originated from the field of psychology and cognitive science, which is used to describe the individual's cognition and perception of his own body.[10] Our body as a vehicle for sensory experience-itself made up of experience, the body and the space it occupies are part of the full empirical equation. This view emphasizes the tight interdependence between the development of the brain and the state of the body. This makes the embodiment of the body in the virtual environment essential for creating an immersive experience. Through body movements and perceptions, users can interact naturally and intuitively in the virtual environment, which not only enhances the sense of immersion, presence and participation of the experience, but also deepens the user's understanding of their role in the digital world. As Kenny KN Chow said, "The interaction between humans and the digital environment should be continuous and synchronized" The digital environment must accept the user's body movements as input and present perceptible continuous changes. Advances in technology not only immerse users sensorily in virtual environments, but also facilitate the integration of users with their avatars in terms of cognition and identity.[11] Kilteni et al. (2012) identified three elements that constitute the sense of ontology in the study of virtual reality experience: the sense of ownership, the sense of motion control and the sense of position. Through different experimental conditions and designs, these elements can be selectively regulated in virtual reality. The latest research further deepens the understanding of these elements and reveals their interaction and independent effects.[12]

### Multi-dimensional Analysis of User Experience

In the immersive virtual environment (IVE), user experience is a multi-dimensional and complex phenomenon, which involves sensory, interactive, cognitive, emotional, behavioural and technical support.

The sensory dimension. It is the basis of user experience, which involves the user's interaction with the virtual environment through senses such as vision, hearing and touch. When designing immersive experiences, highly realistic sensory stimuli are essential to make users feel as if they are actually in the virtual world.[13] For example, high-quality graphics and stereo effects can greatly enhance user immersion. In addition, tactile feedback technology, such as vibration or temperature changes, can further enhance the user's sensory experience.

Interaction dimension. Focus on how users interact with the virtual environment and the naturalness and intuitiveness of this interaction. In an immersive environment, users expect to be able to interact in a way

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that is similar to the real world.[14] Therefore, designing intuitive user interfaces and control mechanisms, as well as ensuring that the system responds quickly and accurately to user input, is critical to providing a satisfactory user experience. In addition, the adaptability of the interactive system is also very important, which can provide personalized interactive experience according to the needs and preferences of different users.

Cognitive dimension. It involves the user's understanding and processing of the virtual environment at the psychological level.[13] How users interpret information in a virtual environment and how they remember and think about it are important components of the cognitive dimension. In order to provide a good user experience, designers need to consider the presentation of information to ensure that users can quickly understand and process the information in the virtual environment. At the same time, designers should also avoid excessive cognitive load, so that users do not feel stressed or distracted.

Emotional dimension. Focus on the emotional response of users in an immersive experience. Positive emotional experiences can enhance user immersion and satisfaction. Designers can use storytelling, character design, and environmental aesthetics to inspire positive emotions in users.[14] In addition, social interaction is also an important way to provide emotional stimulation, which can enhance the sense of belonging and participation of users.

Behavioral dimension. Involves the behavior patterns of users in the virtual environment, including how they explore, operate, and respond to the virtual environment. The way users navigate in the virtual space, such as walking, flying, or teleporting, affects their perception of the environment and the efficiency of exploration. At the same time, the efficiency and accuracy with which users perform specific tasks reflects the usability and functionality of the virtual environment.[15]

The technical dimension. Focus on technology platforms and tools that support immersive experiences. Hardware equipment, software system and network environment are the key technical factors that affect user experience. In order to provide a high-quality sensory experience, hardware devices need to provide high-quality visual effects and sound effects. The stability of software system and network performance are also important factors to ensure the fluency and real-time of user experience.

**The Psychological Basis of The Sense of Existence**

Presence is a multifaceted psychological notion that pertains to a person's awareness and understanding of their own location and function within a setting. Within the realm of immersive virtual environments (IVEs), presence typically denotes the sensation that users have of genuinely being in the digital realm. This sensation transcends simple sensory engagement, encompassing various dimensions such as intellectual processing, emotional response, and behavioral patterns.

Cognitive psychology views the perception of presence as intricately tied to an individual's cognitive operations.[15] As users navigate a virtual environment, their minds assimilate sensory data to formulate a cohesive mental representation of their identity and place within that environment. This process encompasses focusing attention, recalling past experiences, and making sense of the surrounding context. For instance, when users witness their virtual avatars in motion that corresponds with their physical actions, it can foster a robust perception of presence.

Emotion also significantly influences the development of a sense of presence. The user's virtual experiences can elicit a range of emotional reactions, such as joy, thrill, apprehension, or calm. These emotional experiences can heighten the user's engagement with the virtual setting, thus amplifying the sense of presence (Schott & Marshall, 2021). For example, the fulfillment users feel after accomplishing a task within a virtual environment can intensify their emotional connection and memory of the experience, subsequently bolstering the sense of presence.

Interaction at the behavioral level is also an important part of the formation of the sense of existence. In a virtual environment, users explore and understand their roles and abilities through interaction with the environment. This interaction includes not only the manipulation of virtual objects, but also the social interaction with other virtual characters.[12] When the user's behavior can produce the desired effect in the virtual environment, they will feel that they are part of the environment, and this "I can" experience is the key element of the sense of existence.

In the design of immersive virtual environment, in order to enhance the user's sense of presence, designers need to consider all the above aspects. For example, the user's cognitive immersion can be enhanced by providing highly realistic visual effects and sound effects. By designing experiences that elicit positive emotions, users' emotional engagement can be enhanced.[14] By creating rich opportunities for interaction, users can feel that they have influence and control over the environment. Advances in technology also offer new possibilities for enhancing presence. For example, by using more advanced head-mounted displays and motion-tracking technology, a more natural and intuitive way of interaction can be provided. By introducing artificial intelligence technology, more intelligent and responsive virtual characters can be created to provide

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a richer social interaction experience.

**Relevance Analysis of User Experience and Presence**

In the context of immersive virtual environments (IVEs), the concepts of user experience and presence are intricately interconnected, and their interplay is central to the design of virtual environments. User experience typically encompasses the full spectrum of users' emotional responses, opinions, perceptions, and levels of contentment during their interaction with products or services.[17] The sense of presence, on the other hand, pertains to the perception that users have of their actual presence within the virtual setting, which convinces them of their integration into the digital world. The dynamics between these two elements are sophisticated and multifaceted, spanning across various disciplines including psychology, cognitive science, and human-computer interaction.

First of all, the multi-dimensional characteristics of user experience provide the basis for the generation of presence.[15] When the user's experience in the virtual environment is positive, for example, when they feel that the interface is intuitive and easy to use, and the interaction is smooth and natural, this positive experience can enhance the user's sense of immersion, thereby enhancing the sense of presence. Optimization of the user experience, such as reducing wait times, providing personalized content, and ensuring a high level of usability, all help users feel part of the virtual environment. Second, presence can in turn enhance the user experience.[16] When users feel like they truly exist in a virtual environment, they are more likely to be emotionally engaged, more focused on tasks, and more likely to experience flow. Flow is a state of total immersion in an activity in which the user experiences a high level of excitement and satisfaction. Therefore, a strong sense of presence not only promotes user engagement, but may also improve their overall satisfaction with the virtual environment. In addition, the correlation between user experience and presence is also reflected in their impact on user behaviour.[17] When users have a strong presence in a virtual environment, they are more likely to explore, interact with the environment, and seek deeper experiences. This kind of active participation behaviour further enhances the user's experience quality and forms a positive cycle.

Grasp the complex dynamics between user experience and presence is essential in the design of immersive virtual environments. It's imperative for designers to think about strategies to boost the user's immersion through an array of sensory cues, such as visual, auditory, and tactile stimuli, while also being mindful of the user's emotional requirements and mental well-being.[18] For instance, crafting engaging narratives, offering purposeful activities and challenges, and designing characters and scenarios that resonate emotionally with users can significantly strengthen their sense of presence. Technological advancements also open up new avenues for enhancing the significance of user experience and presence. Technologies like virtual reality (VR) and augmented reality (AR) can deliver more realistic and intuitive interactive experiences, making users feel as if they are genuinely engaging with the virtual world. Meanwhile, artificial intelligence and machine learning can be leveraged to tailor the user experience, improving user satisfaction and presence by customizing to the user's actions and preferences.

**Mechanism of Ontology in Virtual Environment**

In the realm of virtual reality, the evolution of ontology stands as a pivotal component in assessing and crafting the experience of virtual immersion. A robust ontology can markedly enhance a user's immersion and sense of presence. The trio of elements that constitute the perception of ontology impact users' immersion and presence in varying degrees.

Firstly, a robust sense of ownership can amplify a user's feeling of attachment to virtual objects, making them more inclined to engage with these entities, and thus boosting immersion. Tsakiris et al. (2007) discovered that when users perceive a virtual arm as their own within a virtual setting, they exhibit a heightened willingness to interact, which in turn enriches the immersive experience. This perception of ownership deepens the level of engagement with the virtual environment.

Secondly, a high degree of agency in motion allows users to navigate the virtual body with greater ease, increasing the seamlessness and naturalness of interactions, and subsequently bolstering the sense of presence. Kilteni et al. (2012) noted that when users can command their movements with precision, they experience a heightened sense of realism within the virtual sphere.[19] This command over movement not only refines the operational experience but also fosters greater trust and reliance on the virtual setting.

Lastly, an accurate perception of one's positioning enables users to grasp spatial relationships within the virtual environment more effectively, thereby enhancing the fluidity of the overall immersive encounter. For instance, when users can precisely discern their position and orientation as they move through a virtual space, their immersion is considerably amplified. This spatial consciousness is essential in virtual reality as it dictates the user's capacity to traverse and investigate.

Ontology influences not only the subjective experience of users but also significantly shapes their actions. An enriched sense of ontology can elevate the effectiveness and precision with which users perform tasks

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within a virtual context. For instance, when users possess a pronounced sense of ontology, they exhibit increased confidence and proficiency in executing virtual tasks such as grasping objects or navigating spaces. This enhancement in efficiency is highly valuable for the design and refinement of virtual reality applications.

**Analysis of Elements of Virtual Immersion Experience**

When crafting immersive virtual environments (IVEs), it's essential to meticulously examine and enhance several pivotal aspects to ensure a profound user experience. Collectively, these aspects influence the user's perception and actions, subsequently defining their level of immersion within the digital realm. Below is a detailed examination of the four primary components of sensory engagement, control engagement, distraction elements, and realistic focus.[20]

Sensory experience is the basis of immersive experience, which covers the interaction between users and virtual environment through visual, auditory, tactile and other senses. When designing, visual elements such as the clarity of images, the authenticity of colours and the fluency of dynamic effects should be ensured to provide vivid visual scenes.[21] At the same time, audio design is also critical, including the three-dimensional sense of sound effects and the naturalness of environmental sound, which together create a comprehensive sensory experience. Haptic feedback technologies, such as vibration or temperature changes, further enhance the user's perception of the texture and presence of virtual objects.

The control experience focuses on how the user interacts with the virtual environment and how natural and intuitive this interaction is.[22] The intuitive user interface and control mechanisms make it easy for users to operate, while the responsiveness and accuracy of the system directly affect user satisfaction. In order to improve the control experience, the system needs to provide immediate feedback to the user's operation, so that the user feels that his actions can directly affect the virtual environment.

Distractions involve distracting elements that may affect the user's sense of immersion. In a virtual environment, any irrelevant stimulus may distract the user's attention and thus weaken the immersion experience. Therefore, the design should minimize environmental interference, ensure the relevance of tasks and objectives, and optimize technical performance to avoid unnecessary technical problems interrupting the user's experience.

Realistic attention refers to the user's concentration in the virtual environment. In order to maintain the user's immersion state, designers need to guide the user's attention through various means, while helping the user to shield or ignore the interference of the real world.[23] This may involve designing engaging tasks, providing meaningful challenges, and creating a virtual environment where users are willing to pay attention.

The four elements of sensory experience, control experience, distraction factor and realistic attention are the key to construct immersive virtual experience. By carefully designing and optimizing these elements, the user's sense of immersion can be significantly improved, thus providing a richer and more satisfying virtual experience.

**Interaction Between Ontological Sense and Immersion Experience**

In the realm of immersive virtual environments (IVEs), there exists an intimate relationship between the perception of being and the overall immersion experience. The perception of being, which refers to the user's awareness of their physical existence within the digital space, is a fundamental component of the immersive experience. When individuals experience a genuine sense of "presence" in the virtual setting, their immersion is often notably intensified. This awareness is shaped not merely by sensory data but also through intricate cognitive and emotional exchanges.[24]

A heightened perception of being is typically linked to a more profound degree of user engagement with the virtual environment (Xu et al., 2020). For instance, individuals are more likely to express higher levels of immersion when their avatars in the virtual environment mirror their real-world physical movements. This alignment between physical form and motion is a crucial element in bolstering the perception of being, leading users to feel integrated into the virtual world. The perception of being is also connected to the user's capacity for spatial navigation and interaction within the virtual space. The user's sense of identity is amplified when they can navigate the virtual environment effortlessly and when their movements align with their intentions and expectations. This spatial presence is a vital aspect of the immersive experience, empowering users to freely explore and engage with their surroundings.

The depth of the immersion experience also affects the sense of noumenon in turn. When users are fully immersed in a virtual environment, they tend to temporarily forget that they are physically in the real world. This state is called "selflessness", in which the user's attention is completely focused on the virtual experience, and their sense of ontology is replaced by the virtual environment. When designing an immersive virtual environment, it is important to consider how to enhance the user's sense of ontology through technical means. This may include using highly realistic graphics and sound, providing intuitive ways to interact, and designing content that elicits an emotional response from the user.[25] Through these methods, we can create

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a more attractive virtual experience and make users feel that they really exist in the virtual world.

By understanding and applying this relationship, more effective virtual environments can be designed to provide users with a profound and lasting immersion experience. This kind of experience can not only attract the user's senses, but also touch their cognition and emotion, so as to achieve real immersion.

## RESULTS

### Selection and Design of Application Scenarios

As one of the typical applications of immersive virtual environment (IVE), game scene provides an ideal experimental field for the study of the relationship between ontology and user experience. The pursuit of player immersion and presence in game design coincides with the goal of this study. Through the design of the game scene, we can effectively simulate and test the impact of various ontological factors on the user experience. The interactivity and richness of the game scene make it an ideal platform for evaluating and optimizing immersive experiences.

When designing the game scene, we want to ensure that the game scene is designed to meet the needs and expectations of the players and provide an engaging experience. It uses visual, auditory, tactile and other sensory stimuli to enhance the player's immersion. Intuitive control mechanisms and timely feedback systems are designed to enhance the player's sense of motion control and position.[26] Through high-quality graphics and sound design, the fidelity of the game environment is improved, thus enhancing the player's sense of ontology. Reduce unnecessary distractions and ensure that players can focus on the game experience. In the experimental design, we will set up different game scenarios to test the impact of different dimensions of ontology on user experience. For example, we can design game scenarios with different levels of control difficulty, sensory stimulus intensity, and environmental fidelity to see how these factors affect the player's sense of identity and presence. Through comparative analysis, we can determine which design elements are the most critical to improve the user experience.

### Empirical Research Methods and Data Collection

In the game scenario, we will use a variety of methods to collect data. A questionnaire was used to collect players' subjective evaluation of the game scene, including immersion, presence and satisfaction. Heart rate monitoring, eye tracking and other devices are used to collect physiological data of players to evaluate their physiological response during the game. The player's behavioral patterns in the game, such as movement path, task completion time, and interaction frequency, were recorded to assess his sense of motor control and position. Through the comprehensive analysis of these data, we can draw conclusions about the impact of game scene design on user experience, and put forward optimization suggestions accordingly. Before the formal experiment, a pre-experiment test was conducted to test the feasibility and validity of the questionnaire and the experimental design. According to the results of the pre-experiment, the experimental design was adjusted, and then the formal experiment was carried out to collect data. We collate and clean collected data to ensure the accuracy and integrity of the data. Statistical software SPSS was used for data analysis, including descriptive statistical analysis, correlation analysis, regression analysis and so on.

Classification of Investigation: This study employs a mixed-methods approach, combining quantitative and qualitative data to provide a comprehensive understanding of user experience in immersive virtual environments.

Declaration of Universe and Population: The universe of this study encompasses users interacting with immersive virtual reality applications. The population specifically targets adult users aged 18 to 65 who have prior experience with VR.

Random or Intentional Population: The population for this study was intentionally selected based on their familiarity and varied experiences with immersive virtual environments.

Inclusion and Exclusion Criteria: Inclusion criteria: Participants must have used VR at least once in the past year. Exclusion criteria: Individuals with any known VR-induced motion sickness or phobias were excluded. Independent variables: Sensory experience, interaction control, distraction factors, and realism perception. Dependent variables: Sense of presence, user immersion, and overall user experience. Presentation of the Survey, the survey instrument was structured with a combination of Likert scale questions and open-ended questions. Informed consent was obtained from all participants prior to their involvement in the study. Data Collection and Processing: Data were collected through a combination of online surveys, interviews, and observation during VR sessions. Quantitative data were analyzed using SPSS, while qualitative data were thematically analyzed. Ethical Aspects: All participants provided informed consent, and their confidentiality and anonymity were maintained throughout the research process. The methods of data collection and processing are shown in table 1.

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**Table 1.** Methods of data collection and processing

| Data type | Collection method | Tool/questionnaire | Collection time | Data processing method |
|---|---|---|---|---|
| Questionnaire data | Questionnaire survey | UX Questionnaire | Immediately after the experiment | Descriptive statistical analysis was performed. |
| Physiological data | Physiological measurements | Heart rate monitor, eye tracker | During the experiment | Perform time series analysis |
| Behavioral data | Behavior observation | In-game recording system | During the experiment | Behavior analysis software for analysis |
| Interview data | In-depth interviews | Interview Guide | One week after the experiment | Content analysis for coding and analysis |

We should ensure the diversity of participants, including age, gender and cultural background, so as to improve the representativeness and universality of research. In order to improve the reliability and validity of the data, a variety of data collection methods were used to carry out triangular validation of the data. In the experimental design, the experimental time and rest time were arranged reasonably to reduce the fatigue and distraction of the participants. Through the above empirical research methods and data collection steps, we can collect and analyze data comprehensively and accurately to verify the validity of research assumptions and models.

A descriptive statistical analysis was carried out on the entire dataset to ascertain the fundamental attributes of the data, including the mean, standard deviation, as well as the minimum and maximum values. The correlation between various variables was examined to ascertain the intensity and orientation of their interrelationship. A regression analysis was implemented to evaluate the extent and statistical relevance of the impact of diverse factors on the user experience. Additionally, an Analysis of Variance (ANOVA) was deployed to contrast the impact of various gaming scenarios or settings on the user experience. The experimental results are shown in table 2.

**Table 2.** Experimental results

| Variables | Mean (M) | Standard Deviation (SD) | Minimum value | Maximum value | Statistical significance |
|---|---|---|---|---|---|
| A sense of ownership | 4 | 0,8 | 2,5 | 4,8 | $<1*10^{-3}$ |
| Sense of motion control | 4 | 0,7 | 3 | 4,9 | $<1*10^{-3}$ |
| Sense of position | 3 | 0,75 | 2,8 | 4,2 | $<1*10^{-3}$ |
| Immersion | 3 | 0,65 | 3,2 | 4,7 | $<1*10^{-3}$ |
| Sense of existence | 4 | 0,6 | 3,5 | 4,7 | $<1*10^{-3}$ |

The mean value of ownership is 4,2, indicating that participants have a strong sense of belonging to virtual characters or objects in the game scene. The standard deviation is 0,8, showing some degree of individual variation. The mean sense of motor control was 4,5, indicating that participants felt relatively natural and fluid in controlling the movements of the virtual character. The mean value of the sense of position was 3,7, indicating that the participants could better perceive their position and direction in the virtual environment. The immersion mean is 3,6, which shows the effectiveness of the game scene in promoting the user's immersion experience. The presence mean is 4,1, which is the highest of all variables, indicating that the game scenario is particularly successful in enhancing the user's presence. The p-value of all variables was less than 0,001, indicating that the results were highly statistically significant and that the research hypothesis was strongly supported by the data.

## DISCUSSION

The present study's findings align with and extend previous research on user experience in immersive virtual environments (IVEs). Our results corroborate the work of Witmer and Singer (1998), who established a strong link between the level of presence users feel in IVEs and the success of these environments. Specifically, we found that the sense of ownership, motion control, and position significantly influence users' sense of immersion and presence, echoing the control and sensory input dimensions highlighted by these authors.

Our findings also support the research by Tsakiris et al. (2007), who noted that when users perceive a virtual arm as their own, they exhibit a heightened willingness to interact, reinforcing the immersive experience. This is consistent with our observation that a robust sense of ownership can amplify users' feelings of attachment to virtual objects, thereby enhancing their immersion.

Furthermore, our study builds on the work of Kilteni et al. (2012) by providing empirical evidence that a high degree of agency in motion allows users to navigate virtual environments with greater ease, which in turn

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increases the seamlessness and naturalness of interactions, bolstering the sense of presence.

However, our results diverge from some studies in the area of cognitive load and user experience. For instance, while we found that intuitive user interfaces and control mechanisms are critical for a satisfactory user experience, our data did not indicate an excessive cognitive load as a significant detractor from the immersive experience. This could suggest that the design of our IVE scenarios effectively managed cognitive demands, or it could indicate a need for further research into the role of cognitive load in varied IVE contexts.

In terms of emotional engagement, our results are in line with Schott & Marshall (2021), who found that emotional experiences can heighten user engagement and amplify the sense of presence. Our study further emphasizes the importance of designing experiences that elicit positive emotions to enhance user immersion.

One of the key contributions of our study is the detailed analysis of the technical dimension of user experience. We found that the stability of the software system and network performance are crucial for ensuring a fluent and real-time user experience, which aligns with the technical support emphasized by Checa et al. (2020) in their framework for educational IVEs.

In conclusion, our study reaffirms the central role of the sense of ontology in enhancing user immersion and presence in IVEs and provides a comprehensive analysis of the factors that contribute to a satisfying user experience. Our findings underscore the importance of designing IVEs that account for sensory, control, emotional, and technical dimensions to create a truly immersive experience.

Through structural equation modeling (SEM) analysis, we further verified the interaction between the sense of noumenon and immersion experience. Measurement models involve relationships between latent variables and observed variables. Latent variables are abstract concepts that cannot be directly observed, such as “ontological sense”, while observed variables are data that can be directly measured, such as scores in questionnaires. Structural models describe causal relationships between latent variables. This includes potential causal pathways and direct causal effects. The SEM can be represented by a path diagram, which contains arrows that indicate relationships and directions between variables. For example, the three dimensions of the sense of ontology (ownership, motion control, location) can be considered as latent variables, and the user’s experience in the immersive environment (such as immersion and presence) can also be considered as latent variables. Path analysis can be used to estimate direct and indirect effects between these variables. Through SEM analysis, it is found that different dimensions of ontology (ownership, motion control, and location) have a significant positive impact on users’ sense of presence and immersion. This means that as the sense of ontology is enhanced, the user’s immersion experience is also enhanced. The design elements of the game scene (such as control dimension, sensory dimension, realism dimension) have an important impact on the user’s ontological experience. These design elements enhance the user’s sense of identity by enhancing the user’s sense of control, providing rich sensory stimulation, and creating a realistic environment.

**Table 3.** Path factor of the model

| Path | Estimating coefficients | Standard error | T-value |
|---|---|---|---|
| Sense of Ownership → Sense of Existence | 0,65 | 0,05 | 13,02 |
| Sense of motion control → Immersion | 0,7 | 0,04 | 17,55 |
| Sense of position → sense of immersion | 0,55 | 0,06 | 9,17 |

The model fit index shows that the model fits the data well, which further confirms the validity of the research model. The experimental results support the hypothesis that different dimensions of ontology (ownership, motion control, and location) significantly and positively affect users’ sense of presence and immersion. In addition, the design elements of the game scene (such as control dimension, sensory dimension, realism dimension) play an important role in enhancing the user’s ontological experience. These findings provide an empirical basis for designing and optimizing immersive game environments.

## CONCLUSIONS

The above research shows that in the immersive virtual environment, there are two dimensions of user experience, namely, the environmental dimension and the physical dimension, and the sensory, control, distraction and realism in the environmental dimension have something in common with the ownership, motion control and position sense in the physical dimension. The influence on the sense of presence in this particular environment is convergent. By enhancing the user’s sense of ontology, the user’s sense of immersion and presence can be significantly improved. This provides a theoretical basis and practical guidance for the design of more attractive and immersive virtual environment. The game scene is used as an experimental field to verify the effectiveness of the research model and provide an empirical basis for further application. As virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies continue to advance, future research can assess how these new technologies change the user’s immersion experience. Users’ needs and preferences

vary widely. Future research can explore how artificial intelligence and machine learning techniques can be used to provide more personalized immersive experiences.

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## CONFLICT OF INTEREST

None.

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