

Application of Extended Reality Technology in the Home Furnishing Industry: A Case Study of IKEA

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Abstract. This paper proposes how extended reality (XR) technology can enhance customer engagement and experience in online home furnishing shopping from the affordance perspective. Through an analysis of the IKEA Place case, it was found that IKEA Place has limitations in sensory affordance, functional affordance does not meet expectations, and cognitive affordance does not provide users with sufficient confidence. These issues lead to insufficient user stickiness and the inability to establish a deep connection with users. Therefore, this paper proposes an XR solution to improve the shopping experience through more comprehensive functional configurations and environmental interactions presented by XR.

Keywords: Affordance, Interaction Design, Immersive Shopping Platform.

1. Introduction

Currently, consumer habits worldwide have shifted from offline to online shopping. Consumers are no longer satisfied with merely practical and comprehensive products; they now have higher expectations for the shopping experience. [1] Research indicates that during the COVID-19 pandemic, older consumers with lower digital skills began to discover and enjoy online shopping, welcoming the safety provided by technology [2]. Compared to offline shopping, online shopping meets users' needs for convenience, price transparency, and a wider selection of products. The trend towards a cashless society has also led to increased online shopping. A survey conducted by the European Parliament in 2020 found that the cashless society has diminished the younger generation's concept of paper money, making them more inclined towards online shopping, thereby increasing online shopping. [3]

However, in the home furnishing industry, traditional online shopping methods still have limitations, such as unsuitable product sizes and difficulty in confirming product quality and materials. Existing solutions mainly involve augmented reality (AR) technology, where consumers can use their mobile phones or computer cameras to virtually "place" furniture in their rooms to see its actual effect and spatial fit. AR technology allows consumers to overlay virtual products in real environments, helping them observe the material details of furniture, clothing, accessories, and other products. For example, through AR technology, consumers can use their mobile phones or tablets to scan products and view the fabric of clothes, the upholstery of sofas, and the wood grain of furniture, enhancing their perception of materials. Guo C and Zhang X (2024) conducted an in-depth survey of major retailers using AR technology, such as Google, Apple, Alibaba, Amazon, and Facebook. The survey results showed that approximately 75% of consumers want to experience AR services when shopping online, 71% of consumers said they would shop more frequently if retailers used AR, and 40% of consumers were willing to pay more for products offered through AR. [4]

In addition to AR solutions, researchers are exploring more possibilities. In 2024, Ritesh Raj and his team proposed strategies to enhance user engagement in online shopping through AR and VR technology, including product virtual fitting, interactive advertisements, and more immersive shopping environments [5]. Thus, immersive online shopping platforms have emerged.

2. Analysis of Research and Application Status

2.1 Definition and Research Status of XR Technology

The concept of AR first emerged in the 1950s. Over the past 70 years, AR has evolved into various definitions [6], however, the mainstream approach defines AR as the combination of digital information with the real world, presented in real-time [7]. The initial approach to "VR" was panoramic painting, which essentially filled an individual's field of vision, making the viewer feel as if they were truly immersed in the scene [8]. Panoramic painting uses perspective contraction to create a sense of presence in the scene, while stereoscopic photo viewers more effectively utilize this concept to create an "immersive" real perception [9]. When people think of VR, most envision a heavy headset that blocks out environmental information while presenting users with information depicting a virtual environment [10].

Extended Reality (XR) is a general term that includes AR, MR, VR, and any technology located at any point on the virtual continuum, even those that have not yet been developed. XR technology refers to the combination of the real and virtual worlds through computers, creating a virtual environment for human-computer interaction. This includes the integration of three visual interaction technologies, achieving a seamless transition between the real and virtual worlds to create an "immersive" experience. As shown in Figure 1, XR builds a bridge for interaction between the real and virtual worlds based on AR and VR. It includes any type of technology that alters reality by adding digital information to the physical or real-world environment, providing more digital information and thus blurring the boundaries between the physical and virtual worlds [11].

In 2019, Elaine M. Raybourn and her team began exploring the challenges and future opportunities in the design of XR immersive information environments [12]. In this article, the metaphor of the holographic deck is expanded to illustrate how information designers, developers, and engineers can achieve some of the characteristics of this fictional computationally enhanced environment to support real-life face-to-face and virtual human learning, collaboration, and information-rich digital storytelling. Currently, XR technology has been applied to performances, retail, healthcare, education and training, and the food industry. In December 2020, Sanika Doolani proposed that manufacturing has entered the highly customized era of Industry 4.0, which relies on the development of XR technology [13]. In 2020, Katy Perry's performance of her new single "Daisies" incorporated AR, VR, and XR technologies, showcasing high-quality virtual production. The performer transitioned naturally from a real environment to a virtual one, where the space expanded, and the performer interacted with virtual elements. The entire virtual environment surrounded the performer, immersing the audience in a whole new world. This demonstrates that extended reality (XR) can enhance the experience and immersion of different scenes, allow real-time interaction with CG content, and improve the realism of object surfaces in the scene, presenting content in an extremely natural visual manner. In 2023, Aguayo and Eame proposed that XR environments provide scaffolded learning points tailored to individual needs while enhancing sensory and embodied experiences. Their research found that XR environments can improve understanding of complex subjects, promote disciplinary literacy, and change attitudes and behaviors [14]. It is evident that this technology will fundamentally transform the way we work, live, and entertain ourselves.

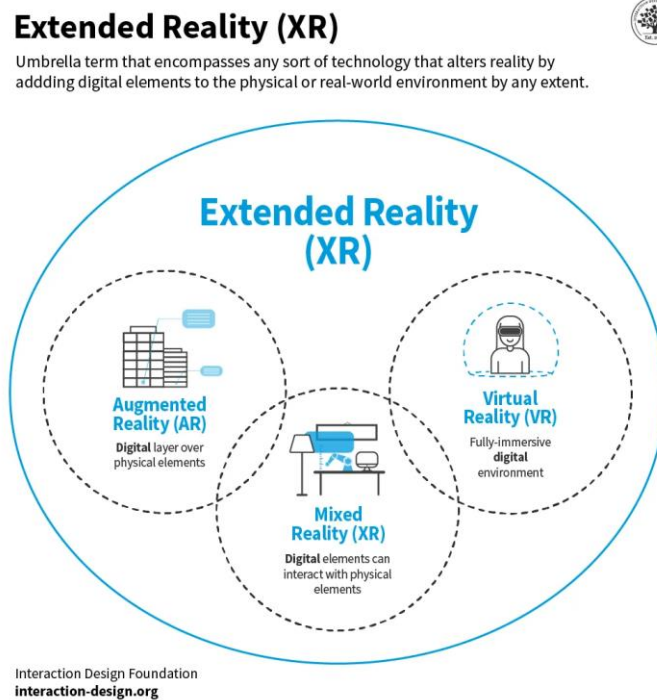


Figure 1. XR Technology

2.2 Application of VR and XR in the Home Furnishing Industry

Currently, various immersive technology furniture shopping platforms are available on the market. For example, in 2016, Lowe's Holoroom project was launched in the North American market. The consumer then enters the Holoroom, which projects a realistic 3D rendering of their future room. Users can also "move anything from furniture to toilets and swap flooring and paint colors by swiping their fingers on the iPad." [15].

In 2016, Wayfair launched Patio Playground. After multiple iterations, in April 2023, they introduced the Digital Design Studio at the AllModern Dedham store. It consists of three main components: 1) the sensing table, which captures the poses of the product cards; 2) a workstation running 3D digital content creation (DCC) software that receives the poses and places and orients the corresponding 3D furniture model in the virtual scene; and 3) a real-time ray-traced renderer that receives the geometry changes and renders a photorealistic image to a display [16].

In April 2016, IKEA launched its VR Experience, marking its entry into the virtual reality field. Users can deeply interact with products in a virtual environment and experience a child's perspective by adjusting the height to realistically simulate different heights in the scene. Users can actively interact with the virtual environment, such as clicking on stoves or cabinets to change colors or materials, opening drawers, and placing pots and pans on the stove. In 2017, IKEA launched the IKEA Place app. In addition to virtual product placement, IKEA Place also incorporated GrokStyle's visual search function, allowing users to identify images with the app without remembering the specific name of an IKEA product. They can find similar products in the IKEA product library and drag them into their real home scenes. IKEA Place can achieve up to 98% product simulation effect in scenes, including lighting and shadows. According to surveys, since the popularization of AR technology, 71% of shoppers prefer stores that offer a "try-before-you-buy" AR experience [17]. In 2020, Heller, J and his team mentioned that using AR (compared to websites) to make creative purchasing decisions sequentially enhances customer engagement, customer creativity, and expected satisfaction [18]. In 2024, Goldenberg, B. mentioned that IKEA achieved \$51.5 billion (476 billion euros) in sales in 2023 using VR technology, with a gross profit margin of 13.2%. [19]. In addition, IKEA Place allows users to preview the placement of furniture in their homes using AR technology.

This reduces the time spent on actual measurements and trial and error. Functionally, IKEA Place utilizes ARKit technology to display furniture in the room with millimeter precision. It also includes a visual search function, enabling users to take photos of furniture, and the app will find similar products in the IKEA product library.

In 2024, A. B. Mishra and his team found through their research on IKEA that the company uses automation and artificial intelligence technology, combined with augmented reality (AR) experiences and virtual reality (VR) showrooms, to enhance user experience and drive business growth. This paper will use interviews and affordance theory to conduct an in-depth study of IKEA Place and IKEA's VR Experience, examining user usage and evaluations, and analyzing existing issues. Affordance theory includes physical affordance, sensory affordance, functional affordance, and cognitive affordance. Physical affordance refers to setting reasonable gestures that conform to people's physical habits for operation while providing intelligent voice assistants to ensure that physical affordance meets expectations. Sensory affordance refers to integrating virtual products into real spaces, combining them with reality, and applying the XR concept to build a bridge for interaction between virtual products and real environments. For example, the collision and friction sounds between virtual products and real scenes, and visual deformation and bending. In addition to visual and auditory senses, different vibration frequencies of joysticks simulate the tactile sensation of different material textures. Functional affordance refers to the need to improve support functions, including shopping carts, personalized product DIY experiences, and product usage tutorials, to provide users with more complete functional affordance and comprehensive services. Cognitive affordance refers to the need to focus on the interaction between virtual products and real scenes, as well as the dynamic changes of virtual products themselves (including the ability to disassemble and assemble products, precise spatial positioning, and rendering effects in real spaces) to stimulate users' deeper understanding of products. It also supports multi-user editing modes to avoid potential cognitive biases, providing users with more complete cognitive affordance.

Through interviews, this paper found the following advantages and issues with IKEA's virtual shopping platform.

Advantages:

- 1) IKEA Place has a simple and easy-to-understand user interface that aligns with users' operational behaviors and habits, providing good physical affordance.
- 2) It solves the problem of size mismatches in online shopping and allows users to see the actual effect of products in their homes, effectively reducing return rates.
- 3) It saves users time and provides a shopping method for those who find it inconvenient to go out.
- 4) The sensory affordance in the VR experience meets users' basic needs, providing basic visual and auditory experiences.

Issues:

- 1) Functional affordance does not meet users' expectations. During user interviews, it was found that the current audience for virtual technology is not broad, and more users still prefer to use the 1: traditional IKEA online store or physical stores. The main reason is that IKEA Place has limited functionality and lacks comprehensive support, such as the inability to add products to the shopping cart for direct purchase.
- 2) Cognitive affordance does not meet the requirements. There is no deeper connection with users, and users lack trust and confidence in the application's functions. Although the user interface is simple and clear, users still encounter various operational issues. Additionally, users can only experience the products visually, without being able to touch and feel the materials, and there are no detailed installation and usage instructions, leading to unfamiliarity with product functions and concerns about potential issues during actual use.
- 3) Lack of personalized experience. The lack of personalized experience makes it difficult to maintain user engagement, attract more users to try the platform, and retain user loyalty.

3. Design of Immersive Shopping Platforms Based on XR Technology

Based on an in-depth investigation of IKEA's virtual shopping platform, this paper optimizes the design of an immersive shopping platform based on XR technology by summarizing its existing problems. The platform design follows three principles: interactivity, entertainment, and social attributes. The design optimization aims to provide users with better affordance, a more complete shopping experience, and more comprehensive sales services. While attracting users, it can maintain good user engagement. Providing social attributes and entertainment can increase user engagement with the application. Users can upload their DIY-designed products and view and comment on other users' DIY products. IKEA can also mass-produce popular DIY products. Additionally, it is necessary to consider situations where multiple members need to make decisions in a shared space, avoiding projection bias.

3.1 Proposed Functional Design

Firstly, from the user's perspective, this paper adds social attributes and entertainment to increase user engagement. Additionally, it improves functional support by adding a shopping cart and supporting multi-user editing, avoiding potential cognitive biases and facilitating better decision-making. From the perspective of home furnishing retailers, it reduces return rates, improves sales efficiency, and lowers the cost of return services.

Cognitive Affordance: When purchasing furniture, the feel and choice of materials are very important. In daily life, people are accustomed to feeling the texture of a material through touch, the sound of tapping, or observing its surface texture. In an XR experience, the roughness of materials can be simulated through different subtle vibration frequencies. By combining the sound effects of tapping or colliding with the material and rendering fine material textures, users' understanding of the material can be enhanced through a combination of visual, auditory, and tactile senses.

Sensory Affordance: Enhance the rendering effects of virtual products (including light source positioning, shadow effects, and material textures), scene positioning, and visual effects (such as adding arrows in product installation tutorials or cracks when products fall to the ground). The auditory aspect mainly showcases the sounds emitted by virtual products themselves (including tapping, disassembling, and installing sounds) and the sounds of interaction with the environment (collisions, friction, squeezing, and tearing sounds). Combined with vibrations of different frequencies, this awakens users' perception of the material of virtual objects, further enhancing immersion through a combination of visual and auditory experiences.

Physical Affordance: By using reasonable gesture controls and user interfaces, system optimization can be enhanced, reducing lag and wait times, thus providing users with stronger physical affordance.

Functional Affordance: Functional affordance revolves around the comprehensive support of the entire shopping process, reducing return rates, and enhancing personalized user experiences. Firstly, adding a shopping cart function meets users' shopping needs. Secondly, adding product installation tutorials and a multi-user editing mode allows users to determine sizes and ensure that the needs of each family member are met, reducing return rates. Finally, adding a DIY product experience enhances personalized user experiences.

3.2 Platform Usage Instructions and Design Effects

- 1) The user enters the scene wearing virtual equipment, as shown in Figure 2.



Figure 2. Design Scene

2) Select the desired product category, as shown in Figure 3.



Figure 3. Select Product Category

3) Move the product to the desired position, as shown in Figure 4.

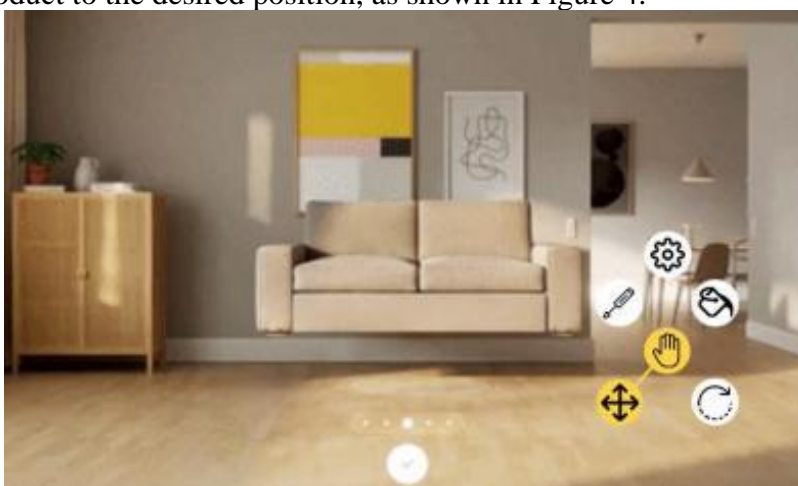


Figure 4. Arrange Furniture

4) Users can change the color or material of the product according to their needs, as shown in Figure 5.



Figure 5. DIY Product Color and Material

5) Users can engage in DIY product design or learn product assembly tutorials. After completing the DIY product design, users can save the results and publish them in the "Life Circle" to showcase their designs to other users. They can also post topics or polls to interact with other users, enhancing DIY design inspiration, as shown in Figure 6.



Figure 6. Disassemble and Assemble Furniture

4. Conclusion

The application of XR technology in shopping platforms can provide users with a richer sensory experience, increase the interaction of virtual products, and enhance the interaction between virtual

products and real scenes. By enhancing the integration of virtual and real, and more realistically simulating products, this paper combines affordance theory to propose relevant suggestions for optimizing immersive virtual shopping platforms for home furnishings and conducts preliminary design implementation. The goal is to increase platform interactivity and entertainment, thereby enhancing customer engagement.

To stimulate users' perception and understanding of product materials and functions, this paper has made efforts in terms of physical and sensory affordance. However, in terms of cognitive affordance, there are still deficiencies in the perception of product materials. Users are still unable to feel the texture and tactile changes of different products through touch. Additionally, due to the wide variety of products and accessories, XR needs to distinguish and recognize environmental light and materials. This means that real-time rendering calculations in the scene involve a large amount of data, which is the future design direction of this paper.

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