Enhancing the Visual Experience: Analysis of the performance and challenges of Stereoscopic 3D technology in game design and virtual reality

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Abstract

In the era of digital innovation, Stereoscopic 3D (S3D) technology is becoming popular in game design and virtual reality, although it faces challenges related to user convenience. This research aims to analyze the challenges and opportunities associated with the use of S3D, as well as to explore best practices for enhancing the user experience. The method employed is a literature analysis that includes the collection and evaluation of sources related to S3D, game design, and user experience. The findings underscore the significance of selecting suitable stereoscopic parameters, understanding perceptual psychology, and integrating emerging technologies, such as Virtual Reality (VR) and generative AI, to craft immersive and comfortable visual experiences. The research also emphasizes the importance of a collaborative design approach to meeting user expectations and mitigating discomfort experienced during interactions with S3D content.
Keywords: Stereoscopic 3D, user experience, game design, visual comfort, immersive technology, Virtual Reality, generative AI, perceptual psychology.

A. INTRODUCTION

Advancements in technology, audience engagement, and mental health issues present some of the current challenges in the field of visual effects animation. The expansion of the industry has tasked animators with striking a balance between creativity and audience requirements, particularly about mental health awareness. Animation is becoming increasingly interesting with the rise of augmented reality and virtual reality (AR/VR). The development of more advanced visual effects is a result of improvements in animation software and devices, which have been modified within the confines of traditional animation techniques.

Creating animations together can greatly enhance young people's mental health literacy and understanding of audience perception because animation involves collaboration among various creators. Effectively educating and communicating interesting and engaging narratives is essential. Content creation aimed at addressing social issues, particularly mental health topics, is increasingly relevant for animation. Animations that foster discussions about mental health can elevate the conversation,

reduce discriminatory attitudes, and serve as an important tool in public health campaigns. However, technological advancements, while intriguing, may cause audiences to become indifferent to the visuals presented, diminishing the impact of the narrative that must be considered in a film.

The 3D Stereoscopic (S3Dimension) visual method can provide a captivating and immersive experience for its new and promising audience, emerging as a solution to the demand for richer and more realistic visual content due to the development of modern technology across various fields, including movies and video games. Although many advancements have been made in this area, significant concerns remain regarding the convenience and affordability of the viewing experience, as well as the limitations of screen technology, according to the latest research.

3D Stereoscopic Technology (S3D) aims to produce three-dimensional images that create a depth effect by utilizing the differences between the human left and right eyes. In his research, Low states that the methods currently used to calculate the topographic parameters of a stereoscopic display often fail to consider the significant interactions between the geometric elements in a scene, the camera, and the viewer, within a two-dimensional space involving convergence and distance cameras[1].

This can simplify the procedures necessary to achieve a deep visual experience. In addition, evidence from Schild and Masuch's study shows that most game designers face difficulties related to the pitfalls of S3D in strategically designing innovative gameplay[2].

Stereoscopic 3D (S3D) offers numerous opportunities, yet the adoption of this technology has consistently faced various challenges. For instance, in the realm of Audiovisual S3D, accurately reproducing depth remains a significant issue. Observations indicate that watching programs in the S3D paradigm can lead to fatigue, ultimately reducing comfort for users or viewers. In line with design advancements, Stereoscopic 3D (S3D) applications include visual functions for 3D images used in various scientific and multicycline geomatic modeling systems. Any response to

[1] Matthew Low, "Creating Better Stereo 3D For Animated Movies," 2011, http://ecommons.cornell.edu/bitstream/1813/29419/1/mml44thesisPDF.pdf.
[2] Jonas Schild and Maic Masuch, "Fundamentals of Stereoscopic 3d Game Design" (Springer, Berlin, Heidelberg, 2011), 155–60, https://doi.org/10.1007/978-3-642-24500-8_17.

technology needs thorough examination regarding its effects on humans. The first gap analysis focuses on the practical application of Stereoscopic 3D (S3D). While Stereoscopic 3D (S3D) is claimed to provide an immersive and comfortable experience, users often face substantial difficulties and visual fatigue.

Improved organization of outdoor literature should not require additional attention or effort from the user. This aspect highlights another discrepancy between theory and practice. S3D regarding VR games and applications does exist, but there is still very little discussion about its relationship with in-game variants[3]. For this reason, further research is still needed to address this issue. This research aims to enhance our understanding of developmental psychology and Stereoscopic 3D (S3D) technology. One objective of this research is to evaluate the challenges and opportunities in developing Stereoscopic 3D (S3D) game design, as well as to provide innovative ideas for Stereoscopic 3D (S3D) game design.

B. RESEARCH METHODS

Stereoscopic 3D (S3D) technology and its applications in game design and user interaction in virtual environments will be studied qualitatively through literature review analysis. The literature review process involves several steps. First, relevant information is collected. Relevant resources include articles, books, conference proceedings, as well as studies on Stereoscopic 3D (S3D), computer game design, virtual reality, and perceptual psychology.

For the second criterion, only literature published in indexed journals or other reputable sources is used. The relevance to the topic, reliability of the source, and year of publication are additional criteria. academic libraries, university libraries, and various digital sources utilize documents that publish data. This research is qualitative and employs content analysis techniques. The primary focus of the research is on the user and stereoscopic 3D (S3D). This study aims to enhance S3D and existing game design. The emphasis is on stereoscopic 3D (S3D) within contextual virtual reality. Research

[3] Hitoshi Ohzu, "Vision Functions Related to 3D Image Display" (Springer, Berlin, Heidelberg, 1997), 183–86, https://doi.org/10.1007/978-3-642-60872-8_26.

sources include books, articles, and relational research reports. Information related to Stereoscopic 3D (S3D) is available through Google Scholar, JSTOR, and other public portals, as well as regarding game design and its relationship to virtual reality. The collected literature will be categorized by S3D topics and user experience, along with the use of Mendeley's reference management software. The data is processed using qualitative content analysis techniques and contextual coding to organize the information. Codes are created for the convenience of both the user and the technology employed. The data will be interpreted to determine the relationships between the emerging topics. Stereoscopic 3D (S3D) can enhance or diminish the user experience based on the functionality at hand, and how advanced technology can facilitate this. Finally, to ascertain the relevance and contribution of the study, the analysis must be interpreted and compared with current literature.

C. RESULTS OF RESEARCH AND DISCUSSION

1. Stereoscopic 3D user experience

Stereoscopic 3D, or S3D, is a technique that creates the illusion of depth by providing two images for each eye, mimicking how humans perceive the world. While S3D delivers an impressive visual experience, some users report discomfort and visual fatigue from using the technology in various settings such as movies, digital games, and virtual reality. As Watanabe and Shimozaki point out, even individuals who do not experience issues with standard 2D viewing can encounter visual fatigue due to extended time spent watching S3D content[4].

About 14% of viewers experience side effects such as headaches and eye strain when watching S3D, according to research conducted by Jenny and Iwo. Another study found that approximately 8% of 3D glasses users who watched 2D content experienced the nocebo effect, or negative expectations about S3D[5].

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[4] Hiroshi Watanabe et al., "Visually Induced Symptoms Questionnaire (VISQ): A Subjective Evaluation Method for Biomedical Effects Induced by Stereoscopic 3D Video," *Applied Ergonomics* 117 (2024): 104238, https://doi.org/https://doi.org/10.1016/j.apergo.2024.104238.

[5] Jenny C.A. Read and Iwo Bohr, "User Experience While Viewing Stereoscopic 3D Television," *Ergonomics* (Taylor & Francis, 2014), https://doi.org/10.1080/00140139.2014.914581.

Karimi, in his research, identified several factors that can cause visual discomfort. These include convergence errors, misalignment between the left and right views, and depth cues conflicts[6]. His research shows that symptoms such as headaches and blurred vision can result from the incompatibility between the images shown together and the natural perception of depth. Additionally, Watanabe and Shimozaki emphasize that watching a long movie without a break can contribute to external influences as well as eye strain health[7]. Applications in the field of digital gaming believe that "the more stereo, the better the experience." However, Takatalo, in its research, found that users don't always have a better experience with more stereo effects[8]. They demonstrated, using the Presence-Engagement-Flow Psychological Framework (PIFF2), that moderate levels of stereo separation positively influence the user experience by enhancing the sense of presence. Therefore, to minimize inconvenience, the design of S3D content should be balanced and ergonomic. Designing S3D content must prioritize user experience. Research by McIntire emphasizes the significance of compliance and subtending parameters on user comfort and satisfaction with the system[9]. Other research by Yang indicates that several factors, including texture, reflection, and even shadows, significantly influence depth view[10]. Current data indicates that online visualization in the field of education is still lacking. However, various industries continue to utilize 3D technology. Multi-dimensional painting and head-tracking technology that can transform images according to user movements is known as S3D and has been introduced since advances in Guindy and Kara's didactics. Therefore, these elements should be considered when designing content using S3D. From the analysis of the

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[6] Maryam Karimi, Mansour Nejati, and Weisi Lin, "Bi-Disparity Sparse Feature Learning for 3D Visual Discomfort Prediction," *Signal Processing* 188 (2021): 108179, https://doi.org/https://doi.org/10.1016/j.sigpro.2021.108179.

[7] Watanabe et al., "Visually Induced Symptoms Questionnaire (VISQ): A Subjective Evaluation Method for Biomedical Effects Induced by Stereoscopic 3D Video."

[8] Jari Takatalo et al., "User Experience in 3D Stereoscopic Games," *Media Psychology* 14, no. 4 (November 30, 2011): 387–414, https://doi.org/10.1080/15213269.2011.620538.

[9] John P McIntire, Paul R Havig, and Eric E Geiselman, "Stereoscopic 3D Displays and Human Performance: A Comprehensive Review," *Displays* 35, no. 1 (2014): 18–26, https://doi.org/https://doi.org/10.1016/j.displa.2013.10.004.

[10] Yang Yang et al., "Depth Perception Enhancement in 2D/3D Vascular Image Fusion," in *Proceedings of the 2021 5th International Conference on Digital Signal Processing*, ICDSP '21 (New York, NY, USA: Association for Computing Machinery, 2021), 46–52, https://doi.org/10.1145/3458380.3458389.

stereoscopic 3D experience, it is evident that this technology can provide an immersive and interactive experience. However, the issues of comfort and depth still require refinement. The focus must be optimized not only on the visual aspect but also on the psychological factors related to ensure that the user experience is more in-depth and comprehensive. In stereoscopic 3D, creating quality and accessible content is also very important.

2. Stereoscopic 3D Game Design Challenge

The concept of combining visual technology and perceptual psychology in designing Stereoscopic 3D (S3D) for games is crucial. This is important because game design faces many complex and even multidimensional challenges. In research conducted by Schild and Masuch, many game designers applied S3D without considering various multitasking errors. This highlights that the study of S3D and its interaction with gameplay is sufficiently deep to be very multifaceted[11].

Game designers can create stunning graphics and comfortable gameplay with the aid of perceptual psychology. For instance, developing a 3D (S3D) game necessitates understanding how users perceive and respond to various visual and auditory cues. Studies indicate that S3D relies significantly on vision and how sound effects and narratives are integrated with visuals. According to Schild and Masuch, a major design challenge is incorporating audio elements that support depth and space to enhance immersion. Inaccuracies in audio can lead to discomfort as well as visual incompatibility.

Stereoscopic visualization is beneficial for interpreting complex geometric properties, as described by Gajski. To evaluate archaeological artifacts that are challenging to view from a two-dimensional perspective, three-dimensional visualization proves advantageous. Researchers can produce more detailed and vivid 3D models using stereoscopic imaging production techniques with software like Blender. This will enhance collaboration and discussions between archaeologists[12].

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[11] Schild and Masuch, "Fundamentals of Stereoscopic 3d Game Design."
[12] Dubravko Gajski et al., "Straightforward Stereoscopic Techniques for Archaeometric Interpretation of Archeological Artifacts," *Heritage* 6, no. 7 (2023): 5066–81, https://doi.org/10.3390/heritage6070268.

Playing stereoscopic or S3D games can improve vision skills globally, and video games can optimize normal vision. This finding, conducted by Li about a year ago, demonstrated that S3D games can serve as an educational and rehabilitation medium, not just a form of entertainment. The study also revealed that in subjects with normal vision, the precision of inward vision increased, although accuracy did not improve. It can be an adjunctive therapy tool for patients with binocular vision disorders[13].

On the other hand, Zhang proposed a game design framework for serious VR rehabilitation (Clinical-Function-Interesting, CFI). This framework incorporates clinical information alongside the functions of the game. It aims to emphasize the systematic approach needed in the design to achieve specific rehabilitation goals by integrating game-like motivational elements, which enhance the appeal of rehabilitation games to patients and encourage their participation over specific periods therapies[14]. The research explains that the design of the S3D system faces several issues that must be resolved immediately to enhance the user experience, making it comfortable and efficient. By understanding perceptual psychology, designers can optimize their psychological potential by effectively combining and correlating visual and auditory elements. A comprehensive outline of how S3D can enhance the user experience is provided through engaging gaming experiences, potential treatments, and applications for archaeologists.

3. Stereoscopic Parameter Use Practices

In stereoscopic 3D (S3D) technology, the use of stereoscopic parameters such as convergence, separation, and depth settings impacts the user's experience with the device. Previous research has shown that visual effects that appear "out of place" in some settings can make players unaware of what is happening and inadvertently ruin the overall gameplay. For instance, research conducted by McIntire demonstrated a direct

[13] Roger W. Li et al., "Playing Stereoscopic Video Games Enhances the Precision but Not the Accuracy of Depth Perception," *Scientific Reports* 14, no. 1 (2024): 1–8, https://doi.org/10.1038/s41598-024-82194-0.

[14] Chengjie Zhang, Suiran Yu, and Jiancheng Ji, "CFI: A VR Motor Rehabilitation Serious Game Design Framework Integrating Rehabilitation Function and Game Design Principles with an Upper Limb Case," *Journal of NeuroEngineering and Rehabilitation* 21, no. 1 (2024): 1–23, https://doi.org/10.1186/s12984-024-01373-2.

correlation between stereoscopic separation and depth perception[15]. When these parameters are not managed properly, they can confuse players, distract them, and ultimately lower their performance. Therefore, designers need to conduct comprehensive user testing to determine the ideal settings and balance for the game's genre and content.

Research on the elements in the vat-polymerization workflow for 3D printing can also be used to assess the application of stereoscopic parameters in the manufacture of medical instruments. Specific 'print' parameters, including 'support' structures, cutting methods, and post-processing techniques, influence the surface roughness, geometric accuracy, and mechanical properties of the resulting dental device[16]. The final result of a device made additively for a specific clinical purpose is ultimately influenced by the systematization of this arrangement. Various practices have been identified, but further research is still necessary to establish optimal manufacturing protocol limitations for polymer dental devices produced.

Della Bona stated that several studies have been conducted in Asia, Europe, and the United States regarding the use of polymer-based restorative materials to create molds. These studies include assessments of the accuracy of surface dimensions, strength, and morphology. Additionally, several studies examined antibacterial response, cytotoxicity, and resistance to fracture and wear. While there are not many studies demonstrating the clinical potential of 3D printing technology, the few that exist have not been implemented in clinical practice. This indicates a growing interest, but the translation to real applications is limited and still in the early stages[17].

1. In general, in S3D, the user experience can be enhanced by using proper stereoscopic parameters. In the manufacturing of dental aids and game design, attention to

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[15] McIntire, Havig, and Geiselman, "Stereoscopic 3D Displays and Human Performance: A Comprehensive Review."

[16] Wenceslao Piedra-Cascón et al., "3D Printing Parameters, Supporting Structures, Slicing, and Post-Processing Procedures of Vat-Polymerization Additive Manufacturing Technologies: A Narrative Review," *Journal of Dentistry* 109 (2021): 103630, https://doi.org/https://doi.org/10.1016/j.jdent.2021.103630.

[17] Alvaro Della Bona et al., "3D Printing Restorative Materials Using a Stereolithographic Technique: A Systematic Review," *Dental Materials* 37, no. 2 (2021): 336–50, https://doi.org/https://doi.org/10.1016/j.dental.2020.11.030.

parameter regulation and their interconnectedness with various components resonates with the successful application of this technology. Further research related to developing optimal and user-friendly products is always directed toward researchers and designers.

4. Growing Use of Display Technology

The latest iteration of Stereoscopic 3D (S3D) technology includes the use of Head-Mounted Displays (HMDs) that can present images in 360 degrees and track head movements. Although HMD surgeon 3D seems attractive, the main challenge is to enhance the realism of the image without causing eye damage or other harmful effects. According to Schild and Masuch, game designers create immersive and comfortable 3D environments for players to explore because creating vivid images of moving volumes against a panoramic background is quite challenging work at the level of interdisciplinary problems[18].

Another field that utilizes advanced technology alongside game applications is 3D printing. Additive printing technology has transformed prototype development in terms of technology, construction, materials, and multiphysical properties. Vat photopolymerization is the most popular technique in 3D printing. This method employs ultraviolet (UV) light to bond the molecular chain of liquid resin that is susceptible to light. This process promotes the bonding of the available resin elements, resulting in the resin becoming rigid. Three technologies—photopolymerization stereolithography (SLA), digital light processing (DLP), and continuous digital light processing (CDLP)—are discussed along with the post-curation mechanical properties of light-confined resin materials in a manuscript written by Pagac[19]. The results aim to provide an overview and future trends in photopolymerization technology, hoping to encourage further research in this area.

As one of the sectors attracting attention, the food industry has succeeded in producing complex 3D prints with smooth textures, and the nutritional content is

[18] Schild and Masuch, "Fundamentals of Stereoscopic 3d Game Design."
[19] Marek Pagac et al., "A Review of Vat Photopolymerization Technology: Materials, Applications, Challenges, and Future Trends of 3d Printing," *Polymers* 13, no. 4 (2021): 1–20, https://doi.org/10.3390/polym13040598.

tailored to specific needs. The development of 3D printing techniques in food has been ongoing since the early 2000s, with the main applications focused on cutting technology[20].

Various ingredients have been used, including cereal and chocolate derivatives, along with innovative cuts of proteins and fiber sourced from insects, algae, and agricultural residues. Although 3D printing presents new opportunities, acceptability remains a concern, significantly influenced by the unconventional appearance of food.

The construction and food service industries are beginning to take advantage of 3D technology, and the application of 3D concrete printing (3DCP) is becoming more advanced. Based on the findings of Ma's research in 2022, if this technique and its supporting applications continue to develop, there is a significant opportunity for innovation in the construction field. This article describes, using public data, articles, and patents, how and for what 3DCP has been applied and developed. Identification reveals that 3DCP is situated at the TRL6-7 technology readiness level (TRL), which is equivalent to the polymer-based fusion deposit modeling process[21].

The application of new display technology certainly affects the S3D user experience both at the game level and in practical applications such as 3D printing across various industries. Both HMDs providing visually immersive experiences and innovative uses of 3D printing in food and construction bring new challenges and opportunities. Researchers and designers must innovate technology for greater convenience and effectiveness. In this case, issues related to acceptability and efficiency are also challenges that must be addressed solved.

5. Balance between Creativity and Practicality

Game designers should be expected to incorporate stunning visuals into their work while remaining mindful of the technical limitations within the scope of Stereoscopic 3D

[20] Antonietta Baiano, "3D Printed Foods: A Comprehensive Review on Technologies, Nutritional Value, Safety, Consumer Attitude, Regulatory Framework, and Economic and Sustainability Issues," *Food Reviews International* 38, no. 5 (2022): 986–1016, https://doi.org/10.1080/87559129.2020.1762091.
[21] Guowei Ma et al., "Technology Readiness: A Global Snapshot of 3D Concrete Printing and the Frontiers for Development," *Cement and Concrete Research* 156 (2022): 106774, https://doi.org/https://doi.org/10.1016/j.cemconres.2022.106774.

(S3D). This creates a conflict between the semi-creative and semi-technical realms that must be addressed in the design process. For example, a game with high S3D visibility requires a compelling and coherent narrative. According to Schild and Masuch, to ensure a satisfying gaming experience, it is essential to understand how players behave and how they perceive the S3D environment[22].

Vo in 2024 highlights how the creativity of Interior Design students increases when working on lighting design projects due to the use of VR and 3D printing technology. The findings of this study suggest that there is a direct relationship between effective control over the 3D printing process and adequate access to VR technology, as both factors significantly enhance creativity in projects parameters[23].

The application of IVR 3D modeling in primary education has significant potential for enhancing problem-solving abilities as well as creative thinking skills. According to research by Chen, the IVR approach not only helps students understand abstract concepts more easily but also provides cognitive relief during the learning process. By combining IVR and 3D modeling, students can engage with virtual learning environments, which boosts their creativity and problem-solving abilities[24].

On the other hand, the development of AI technology, which is generative, presents new challenges and opportunities in the creative industry. Amankwah-Amoah argues that the adaptation of artificial intelligence will be successful if there is a balanced proportion between the use of technological innovation and the maintenance of the integrity of human creativity. Generative AI can serve as a tool for creative professionals to discover new ways to create, accelerate creative activities, and streamline the workflow process. However, maintaining the elements of humanity and authenticity that characterize the products of the creative industry remains a challenge[25].

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[22] Schild and Masuch, "Fundamentals of Stereoscopic 3d Game Design."
[23] Hoa Vo, "Design Creativity in Industry 4.0: Gravity Sketch and 3D Printing in a Luminaire Design Project," *Journal of Engineering, Design and Technology* 22, no. 5 (January 1, 2024): 1413–32, https://doi.org/10.1108/JEDT-01-2022-0053.
[24] Shu Jie Chen, Chuang Qi Chen, and Xiao Fen Shan, "The Effects of an Immersive Virtual-Reality-Based 3D Modeling Approach on the Creativity and Problem-Solving Tendency of Elementary School Students," *Sustainability (Switzerland)* 16, no. 10 (2024), https://doi.org/10.3390/su16104092.
[25] Joseph Amankwah-Amoah et al., "The Impending Disruption of Creative Industries by Generative AI: Opportunities, Challenges, and Research Agenda," *International Journal of Information Management* 79 (2024): 102759, https://doi.org/https://doi.org/10.1016/j.ijinfomgt.2024.102759.

To create a satisfying user experience, a designer must strike a balance between imagination and practicality in the realm of S3D. While technologies like virtual reality, interactive virtual reality, and generative artificial intelligence provide new tools for innovators, there has always been a need for a comprehensive understanding of user interactions with technology. By continuously exploring and optimizing technology, designers can craft more immersive and enjoyable experiences.

Previous research has shown that involving players in the design and testing process can be helpful in determining the best parameters and getting valid feedback. This is crucial to ensure the design meetusers' needf users and expectations. S3D game design must accommodate the ability to operate on both 2D and 3D screens. This way, players who don't have an S3D headset can still enjoy an optimized gaming experience. A good service to teach users the best way to enjoy S3D content and inform them about fatigue or visual issues when interacting with it is also important. The difficulty of S3D game design is a multidimensional problem that requires an understanding of technology, psychology, and aesthetics. Ultimately, to succeed in the world of S3D-based gaming, designers must carefully balance technical settings with user needs to create a stunning gaming experience. To drive further innovation in this area, interdisciplinary research and collaboration are essential.

A. CONCLUSION

Although Stereoscopic 3D (S3D) technology has great potential to create exceptional visual experiences, evaluating its performance and the challenges it faces in video games and virtual reality is essential. The technology encounters several issues, including visual discomfort and user fatigue. In such situations, designers must find a way to balance the creative and technical aspes along well as how the user perceives the design.

Research indicates that factors like stereoscopic parameter positioning, visual features, and the integration of audio elements are crucial for crafting an enjoyable and satisfying experience. The implementation of new technologies, including generative AI

and VR, can enhance the user experience, provided they are aligned with the user's authenticity and needs.

The study also recommends a collaborative design approach that integrates users into the game development process to ensure the final product meets expectations. To address the challenges of S3D, both in the context of games and other practical applications, it is essential to understand perceptual psychology and to adopt an innovative approach to content design.

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