New Design Ideas
Vol.9, No.2, 2025, pp.450-468
https://doi.org/10.62476/ndi.92450

AUGMENTING VISUAL IMMERSION WITH LIGHTING DESIGN IN A METAVERSE EXHIBITION SPACE

Bella Zulita Muharani[1], Deny Willy Junaidy[2*]

[1]Master's Program in Design, Faculty of Art and Design, Bandung Institute of Technology, Bandung, Indonesia
[2]Human and Interior Space Research Group, Faculty of Art and Design, Bandung Institute of Technology, Bandung, Indonesia

Abstract. The East Hall of Ganesha Campus, Bandung Institute of Technology (ITB), one of the most active heritage venues, faces challenges in adopting modern technology to better serve and engage global audiences. This study explores the lighting potential in a metaverse exhibition space at the Bandung Institute of Technology. The exhibition featured the works of two senior artists using the exaggerated design technique to primarily explore positive and negative emotional valences. Temporal variations were employed to create color and lighting configurations for eliciting emotional responses in virtual reality (VR). The design process involved 3D Studio Max and AutoCAD for modeling, Unreal Engine for the lighting configuration and various lighting techniques. The applied methods produced realistic effects, enhancing the metaverse environment to facilitate a captivating VR experience. The lighting design was tested with 28 respondents to evaluate positive and negative design themes in VR. Positive stimuli, characterized by brightness and rich colors, motivated further exploration, whereas negative stimuli, characterized by dimness and low color temperature, created tension and reduced interest in the interaction. Therefore, lighting plays a central role in shaping respondents' experiences.

Keywords: *Lighting, metaverse, exaggerated design, virtual reality, exhibition space, emotional valences.*

Corresponding Author: *Deny Willy Junaidy, Human and Interior Space Research Group, Faculty of Art and Design, Bandung Institute of Technology, Bandung, Indonesia, e-mail: denywilly@itb.ac.id*

Received: *23 September 2024;* ***Accepted:*** *4 February 2025;* ***Published:*** *2 August 2025.*

1. Introduction

The ITB East Hall, a historic and iconic building on the Ganesha Campus, serves as one of the busiest venues for conferences and events throughout the year. Despite its rich heritage and cultural significance, it struggles to meet the evolving demands of modern audiences, particularly in delivering engaging and immersive experiences. The lack of advanced technological integration limits its ability to host hybrid or virtual events, which are increasingly essential for attracting a global audience. This gap not only reduces its competitiveness as an event venue but also hinders its potential to connect with international participants who cannot attend in person. Upgrading the hall with modern technology could preserve its heritage charm while transforming it into a world-class facility that caters to both local and international audiences' needs. An exaggerated visual experience was crafted through the enhancement of lighting potential in a metaverse exhibition space at the East Hall of Ganesha Campus, Bandung Institute of Technology (ITB), attracting attention in the realms of art, design and technology. The three-dimensional (3D) virtual environment of a metaverse offers various opportunities for interaction and exploration. Respondents report a sense of immersion when engaging

in a game within a virtual space, as it creates an impression akin to a real-life environment (Perron, 2005). In a metaverse exhibition space, lighting design plays a critical role in fostering a rich visual experience. The combination of surreal elements with technology results in a mix of reality and fantasy (Henz, 2022). The experience within the exhibition space is not only visual but also emotional.

The identification of the two poles of lighting valence, represented as positive and negative emotions, can be utilized to validate the responses of participants. According to Isbister (2016), integrating emotions into lighting designs enhances the overall experience. Furthermore, it contributes to an immersive gaming experience for players (Akay, 2022). Positive emotions encompass feelings of joy, fascination, calmness and entertainment, while negative emotions include tension, mystery and suspense. Combining these two emotional valences through lighting design can create an engaging experience in a virtual environment. Various lighting arrangements can produce changes in perception and act as effective tools for eliciting emotions (Kim & Mansfield, 2021). Different effects, such as light intensity, models, animation, glowing light, color, brightness and dimness, have been examined in the field of lighting design (El-Nasr, 2004). The impact of light on mood allows for the creation of specific atmospheres tailored to the desired representation of a room (Quinn & Rohrbaugh, 1981).

This study focuses on the lighting potential of an exhibition space using exaggerated elements. According to Adharamadinka and Junaidy (2022), using virtual reality (VR) in design optimizes visual effects and proves the technology's efficiency in reinforcing mental imagery. A metaverse environment is a platform that evokes emotions and facilitates richer and more immersive experiences (Steinhaeusseur *et al*., 2022).

The designs and experiments conducted in this field are expected to stimulate advancements in digital art and design. Despite the growing importance of lighting design, research focusing on the metaverse exhibition space in the East Hall of the Ganesha Campus at ITB, which features exaggerated characteristics, remains limited. As an institution promoting innovation and the latest technological developments, the Ganesha Campus continues actively experimenting with digital modeling applications. The goal is to create a distinctive metaverse version that provides a virtually immersive and captivating effect, setting it apart from traditional non-virtual exhibitions.

2. Metaverse: Background Interaction with Visualization

In the metaverse exhibition space at the Ganesha Campus, integrating lighting with interactive technology provided an immersive experience for respondents. This integration connected the physical and virtual worlds, merging them into a unified reality. Visual construction was based on graphic techniques and contributed to creating an interconnected world that extends across evolving spaces (Fonnet & Prié, 2019). By leveraging concepts such as lifelogging, collective space in virtuality, the spatial Internet, world mirrors and the omniverse (Bruun & Stentoft, 2019), the exhibition space was strategically designed to create an entertainment atmosphere. Those studies showed the complexity and varied features essential to the visual design of exhibition spaces, providing an absolute understanding of the experiences offered.

The metaverse exhibition space was carefully designed to deliver an alluring visual experience. It used interactive technology, particularly VR and dynamic lighting. The respondents interacted directly with 3D sculpture installations in the East Hall of the Ganesha Campus.

According to Belk (2013), despite the constraints posed by the digital environment, particularly the dematerialization (i.e., products exist solely in digital form without physical embodiment), VR allows users to control lighting settings and other visual elements. This enhancement not only elevates the functionality of the metaverse environment but also contributes to the sustained efficiency of players by effortlessly incorporating physical activities both in and outside display sessions (Yoo *et al*., 2018). Each respondent can customize the exhibition atmosphere according to their emotional valence preferences, which facilitates engagement with the exhibition space, thereby creating a personalized experience.

The combination of metaverse and VR technology creates a visual interaction experience that provides a measurable simulation of real-world scenarios (Zhang *et al*., 2020). Incorporating real-time interactive information displays allowed respondents to gather information about activities while exploring VR environments, fostering a precise and comprehensive understanding of the data (Few, 2006; Junaidy *et al*., 2024; Mahardika *et al*., 2023).

3. Lighting Techniques in Game

As interactive environments, video games can evoke complex emotional responses from players (Graja *et al*., 2020). These emotional reactions are influenced by players' perceptions of digital lighting within the game (Deterding *et al*., 2011). Analyzing lighting characteristics is crucial for understanding perceptions of digital lighting and its impact. This analysis reviews the physical setup and environmental contexts of a game with intensive lighting design prevalent in the market. The goal is to create optimal lighting models by automatically adjusting design techniques based on interactions and scenarios within the game (El-Nasr, 2004). This study draws insights from six 3D games currently on the market, demonstrating that lighting effects can convey excitement and tension (Cornelio *et al*., 2022). Figures 1 and 2 specifically focus on players' experiences with VR simulations designed to enhance the performance of lighting effects and their application in the interactive world.

3.1. Enjoyable Adventures

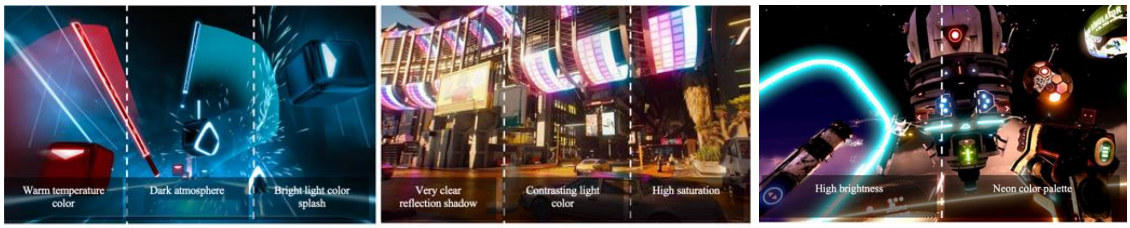


Figure 1. (a) Beat Saber, (b) Cyberpunk 2077 and (c) Space Pirate Trainer. VR simulation games as examples of colorful and enjoyable lighting

a. Figure 1a depicts Beat Saber, a rhythm game that combines the beat of music with light swords in a VR setting. With various levels and unique environments, the game features a futuristic neon aesthetic. The strategic use of bright lighting, vivid colors and strong highlights enables players to quickly identify and respond to rapidly appearing blocks during gameplay. The lighting changes sync with the tempo and musical tones,

creating an interactive experience closely tied to player movements. Complementary visual effects, such as light splashes, particles and energy waves synchronized with player and object movements, enhance the overall sensation of gameplay. When players successfully navigate challenging sections or complete a level, the lighting shifts to convey a sense of victory and accomplishment. Thus, the lighting in Beat Saber defines the game's character and plays a crucial role in creating an atmosphere that enriches the gaming experience Figure 1b displays Cyberpunk 2077, which engages players in the atmosphere of Night City with futuristic elements. In this game, the entire city is illuminated with neon lights and spotlights on tall buildings, streets and billboards. This visual display contributes to the realism of the game environment. Lighting in this game is not static but dynamically changes depending on environmental conditions and the time of day. Day and night transitions aim to create different moods, while weather conditions, such as rain or fog, also affect the reflection and transmission of light. The significance of lighting is crucial in combat situations or dangerous scenes, creating a dark, intense and occasionally menacing atmosphere. This contributes to the futuristic light effect that enriches players' visual experience and influences their emotional engagement. Therefore, with a significant impact on the atmosphere and immersion in the game, lighting is perceived as an important element in the Cyberpunk 2077 gaming environment.

b. Figure 1c shows the Space Pirate Trainer, a VR game set in a dynamic space environment in which players are tasked with shooting fast and intense balloons. In this game, light characteristics play an important role in creating a futuristic atmosphere and helping players respond effectively to enemies and the surrounding environment. Upon shooting, weapons emit flashes of light and additional effects, providing visual feedback to the player's actions. This extends to the use of other equipment, such as shields or grenades, where light effects assist players in tracking and responding to in-game situations effectively. Moreover, enemies in the game emit light and create special visual effects during attacks, making it easier for players to identify and respond to dangerous situations. These dynamic light characteristics tend to change depending on game conditions, particularly when reaching more intense advanced levels. The evolving lighting effects collectively contribute to a heightened sense of tension during the gaming experience. The use of strongly contrasting colors in lighting helps players clearly distinguish each game element. A dark background featuring dangerous enemy scenes focuses on the targets, thus guiding players.

Effective lighting plays a crucial role in shaping the atmosphere of these three games, significantly aiding players' comprehension while delivering powerful visual effects. Each game employs a unique lighting technique that aligns with its type and purpose, creating distinct moods and enhancing the gaming experience. By using bright neon colors, high-contrast visual effects and dynamic lighting changes, these games establish an ambiance that complements their themes. Beyond its aesthetic appeal, lighting helps players respond to in-game situations with accuracy. Thus, it serves not just as an additional feature in VR game design but also as a tool for improving player understanding and crafting an immersive and captivating gaming experience. Further references to the strategic use of lighting in VR game design can reinforce these insights and provide a comprehensive context for developing this perspective.

3.2. Full of tension and frightening scenes

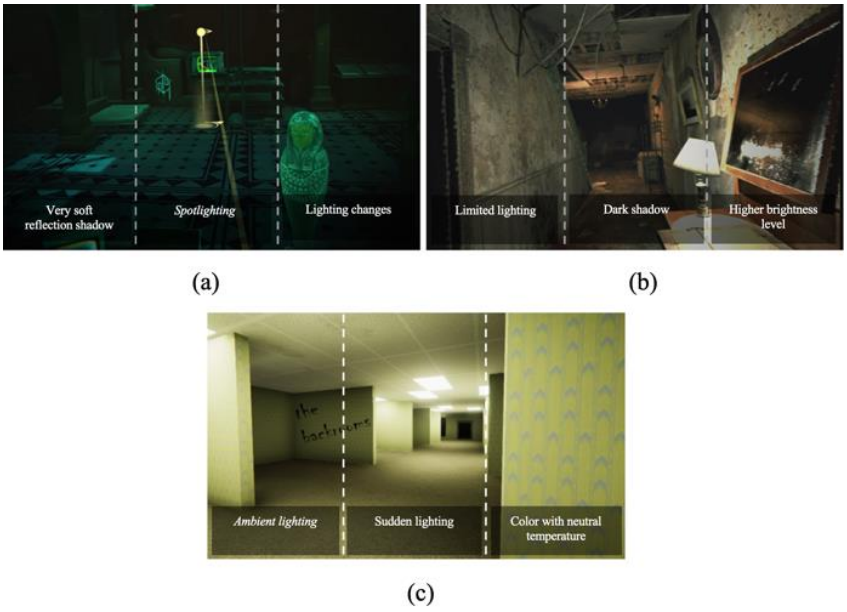


Figure 2. (a) The Room VR: A Dark Matter, (b) Resident Evil VII and (c) The Backrooms. VR game simulations as a reference for lighting in tense and frightening scenes

a. Figure 2a of the game The Room VR: A Dark Matter shows the significant role of lighting in shaping a mysterious and frightening atmosphere during puzzle-solving. Lighting elements function as visual complements and instruments that guide players through dark and mysterious spaces. Lighting creates the illusion of depth and enhances the visual realism of the game by producing accurate shadows and reflections. Various light sources, such as candles, lanterns and torches, provide significant visual effects in the environment. The strategic use of light not only steers players toward essential puzzle elements but also uncovers secrets and forms complex patterns, presenting a captivating challenge. The use of sharp and contrasting light is instrumental in showing important details in the room and creating an atmosphere of curiosity and tension. The applications of shadow and soft light contribute to the mysterious atmosphere and intensify the curiosity of players. During crucial moments, spotlighting adds dynamism to the game, highlighting specific objects and adapting to events or transitions between areas. Lighting in The Room VR: A Dark Matter serves as a directing instrument that enhances the immersion, suspense and mystery of the gaming experience.

b. The game Resident Evil VII, shown in Figure 2b, is a typical example of how lighting significantly creates an intense horror atmosphere. In this game, physically based lighting has a significant visual impact; therefore, it is a contributor to the overall success of the gaming experience. Various lighting techniques are used to create the atmosphere of the game. Light sources in the game generate shadows, reflections and light scattering based on the physical characteristics of the objects and the surrounding environment. The deliberate use of dark and dim lighting is the main tool for inciting feelings of uncertainty and tension, thereby facilitating the full immersion of the players. Nevertheless, bright light provides some comfort and an understanding of the surrounding environment, creating a controlled dynamic between tension and relief. The strategic use of shadow and light effects is effective in concealing threats and fostering a tense atmosphere that significantly influences players' emotional responses. In some scenarios, lighting

dynamics are crucial, requiring players to judiciously use light sources or adapt to their changes. This feature adds a strategy level to the game, increases tension and causes players to explore dark environments reluctantly.

c. Figure 2c of The Backrooms game shows the compelling role of lighting in creating a mysterious and frightening atmosphere, even in non-VR gaming environments. In this game, evenly distributed soft background lighting plays a crucial role in establishing a dark and mysterious ambiance in the virtual space. The placement of lighting points is used to show specific areas, focusing on mysterious elements, such as hidden objects, strange creatures, or tense environments. This strategy helps create a distorted and tense atmosphere, implying potential dangers for players to detect. Hidden light sources, such as candles, flashlights, or flickering lights, are used with maximum effect to add an element of anxiety and intensify suspense. Dynamic lighting systems that can change over time or are based on the activities of players (e.g., light that dims, flickers, or even goes out when the player passes through a certain area) add an extra dimension to the game by introducing uncertainty and anxiety. The implementation of realistic graphics, including accurate shadow effects and dynamic lighting adjustments as objects move, enhances the immersion in the gaming experience. The main aim of this game is to successfully create an immersive and suspenseful playing experience reinforced by the effective use of lighting elements.

In the three games, lighting characteristics play a significant role in influencing emotions. Through the intelligent and precise use of light, developers can enhance immersion levels and explore themes in line with specific genres, specifically horrific types (Graja *et al*., 2020). In addition, light adds dimensions to the gaming environment and illuminates and darkens specific areas, creating diverse virtual landscapes. The use of diverse light sources, combined with visual effects, such as shadows and reflections, as well as invisible dynamic lighting, contributes to the creation of a tense, immersive and mysterious gaming experience. A mysterious atmosphere can be achieved by minimizing lighting and focusing on specific objects, thereby providing a challenge for players (Graja *et al*., 2020).

4. Lighting Design Guidelines: Negative and Positive

In the exploration of lighting design, this study acknowledges that the creation of a particular mood and eliciting emotions are crucial aspects that require attention. Lighting design governs the physical illumination and evokes emotional responses from respondents in the metaverse exhibition space. Quinn and Rohrbaugh (1981) stated that this perspective was enriched by the insights of two design experts who explored the application of emotional experiences in spatial design. Furthermore, Jicol et al. (2021) stated that positive and negative emotional valences enhance the sense of presence and contribute to the meaningful creation of a virtual experience (Skarbez *et al*., 2018).

This study focused on examining positive and negative lighting models as the main determinants shaping emotions (Plutchik, 1982). This is consistent with the investigation conducted by González-Martín et al. (2022), who stated that positive emotions include joy and calmness, whereas negative ones manifest as anger and fear. Through this literature analysis of existing research, concrete guidelines for designing lighting are summarised to ensure that it can effectively induce both positive and negative emotional responses.

1. Positive Lighting

Positive lighting design in exhibition spaces is crucial for creating a pleasant and calming atmosphere. González-Martín et al. (2022) and Li et al. (2021) stated that the strategic use of diverse light sources can create maximal color characteristics, resulting in an atmosphere of joy. The selection of room colors, which is influenced by individual preferences and experiences of individuals (Kuller *et al*., 2006), is a major element in triggering positive emotions. It is also important to create harmony among light-oriented objects to establish a pleasing visual experience (Ellsworth & Smith, 1988). In line with this perspective, bold and bright color choices were balanced with appropriate general lighting placements and additional sources to ensure optimal lighting for each exhibition area.

2. Negative Lighting

A gradual technique for designing a frightening atmosphere aims to create a deeply immersive virtual experience for players (Graja *et al*., 2020). With respect to fear induction stages adjusted for high arousal and negative valence (Russell, 1980), this design leads to the arousal of emotional responses, such as worry, tension and disturbance (Garner & Grimshaw, 2011). Kong et al. (2022) stated that high contrast in dark areas and uneven light distribution created a mysterious ambiance and deep sorrow. This type of atmosphere is further intensified by dominant dark-colored backgrounds and subjects and by the use of only monotone lighting colors (Kauppien-Räisänen & Luomala, 2010). To maintain the practical functionality of the exhibition space, the design maintained low brightness levels to prevent players from becoming frustrated. This is consistent with the research conducted by Kaya and Epps (2004), who stated the importance of considering the preferences and experiences of players in the design process for an immersive and terrifying horror genre experience. Therefore, each design element is carefully selected to create the desired atmosphere and enhance player engagement.

Understanding the dynamics of positive and negative emotions guides the selection of suitable lighting design themes for exhibition spaces. The main focus is to provide a heightened emotional experience for respondents while simultaneously making an impact as they explore the metaverse environment. Exploring lighting design in the metaverse focuses on creative manipulation to present a variety of unique lighting experiences. These designs can be more directed and measurable, creating a profound exploratory experience for users and delivering a stronger impact in the metaverse environment.

5. Method

Advancement of the lighting process comprises a series of structured stages using an integrated multimedia development method in a metaverse environment, as shown in (Figure 3). The design stage involved processes from the inception of ideas to the critical evaluation phase to effectively integrate exaggerated lighting elements into the complex framework of the metaverse environment.

Data were collected through experiments and positive and negative lighting designs were verbally evaluated by 28 respondents, consisting of 17 female and 11 male students aged 19 to 27 years old. Each participant explored the metaverse environment by navigating through the four sections of the exhibition space using the VR Oculus Rift S device for a duration of 8 minutes. The experiment was evaluated by using the think-aloud method. Through active participation, this process aims to identify the success of lighting design and its impact on the respondents' experience of the metaverse exhibition

space. Positioned as an initial step in lighting development, this design test provides a straightforward data collection analysis. The aim was to comprehend visual effects from respondents' perspectives, including contributing to further advancements in the use of lighting in the metaverse exhibition space.

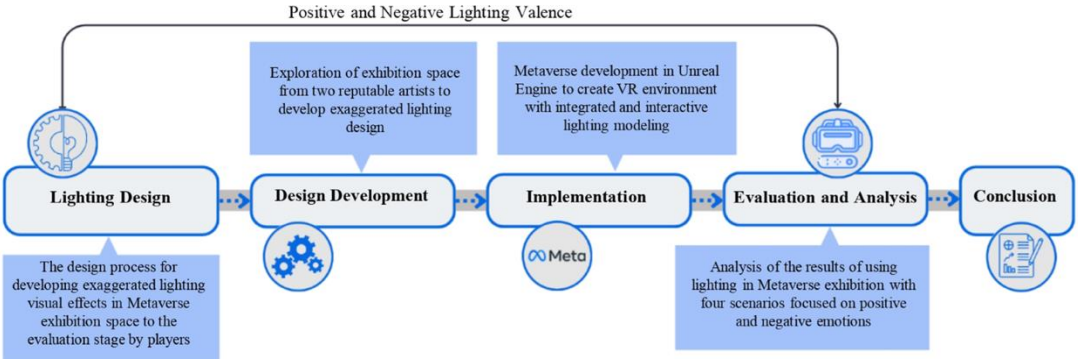
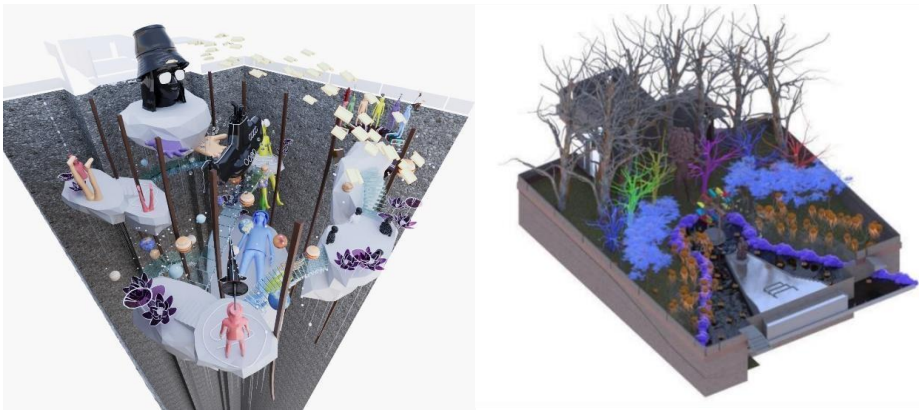


Figure 3. Integration of exaggerated lighting in metaverse: Comprehensive technique from design to evaluation

6. Development of Lighting in Metaverse Exhibition Space

6.1. Design Development

According to Alex Ryandi's Master's Degree thesis (2023), the creation of an exhibition space design involves a collaborative undertaking by two respected artists. The design experiments focused on exploring the scale and form of the space through exaggerated space modeling. The results were used to develop a lighting design that specifically explored two main design concepts: positive and negative emotions.



(a) (b)

Figure 4. Two exhibition design models from two artists: (a) Limitless Life and (b) Mother Spring

a) Figure 4 (a) Limitless Life:

This design concept incorporates hovering objects to produce a dramatic and eccentric effect, thereby producing a unique visual sensation and experience. Exaggerated sculptural forms of various sizes and parts, including large and small sculptures, create a striking presence in this work inspired by Asmudjo Jono, an artist whose pieces were shown in the space. These included staircase leveling and geometric

objects crafted according to the artists' creativity. In addition, different colors were used to intentionally augment the general aesthetic appeal of the exhibition space (Figure 4a).

b) Figure 4 (b) Mother Spring:

The design incorporated the metaphor of a parasite on a plant, depicting the dual nature of human behavior in its potential to damage and improve the environment. The statue in the middle of the pool symbolized health and harmony, creating an inviting atmosphere for the respondents. The clear blue water surrounding the central mother statue contrasts with the pinwheel installation at the back, which narrates the story of a dirty water treatment process connected to a self-portrait known as a parasite plant. The exhibition space aimed to provide an interesting experience and raise awareness about the human impact on the environment and its enhancement through ongoing efforts (Figure 4b).

The main concept for the exhibition is to showcase the characteristics of negative and positive emotions portrayed in each artwork. To address this issue, lighting design is crucial for establishing a more suitable equilibrium. The application of exaggerated lighting design aims to achieve harmony by modeling a design with positive and negative emotional valences. This technique includes modeling lighting designs specifically fabricated to accentuate and negate certain aspects of exhibition spaces. The space uses lighting as a source of illumination and a guiding device that shapes the perception of respondents and their interpretation of the exhibition space to create a more balanced experience.

6.2. Implementation

Creating a metaverse environment in Unreal Engine requires planning and technical skills. The initial stage required the use of 3D Studio Max and AutoCAD software to model the objects, characters and environments. These objects play a significant role in the lighting setup and contribute to establishing a special atmosphere in the virtual exhibition space. This process continues to evolve with the use of Unreal Engine as the main foundation, allowing for a realistic-looking artificial and natural lighting atmosphere to enhance the immersive experience.

The design process continued by integrating interaction systems and developing complex lighting scenarios to enhance user engagement in virtual environments. By utilizing Unreal Engine and implementing tools, such as Blueprints or the C++ programming language, we were able to achieve the desired level of interactivity. To increase the interaction and immersion level of the players, characters and objects are strategically introduced into the environment. Furthermore, in the performance optimization stage, crucial measures such as setting the level of detail to manage the object complexity, determining the number of polygons and implementing frustum culling were carefully addressed. These optimizations are essential for delivering a smooth VR experience that responds to users' movements. Debugging plays an important role in identifying and resolving issues that arise during product testing, thereby ensuring a responsive experience.

To fulfill all aspects, an interactive experiment involving 28 respondents aged 19-27 years old was conducted. The respondents were asked to explore four different metaverse exhibition space setups and provide their responses related to the positive and negative emotions within each space. The experiment was conducted to ensure the proper functioning of every element. When an issue was found during product testing, debugging was performed to identify and address the problem. The establishment of 11

positive and eight negative design guidelines was part of this comprehensive technique. These guidelines were crafted to either enhance the user experience positively or address potential issues that could result in negative experiences. An overview of the guidelines for generating appropriate light modeling depending on whether the intention is to evoke more positive or negative emotions in the metaverse exhibition space is shown in Table 1.

Table 1. Positive emotional state guidelines aligned with conflicting negative guidelines

		Positive		Negative
Design Theme	1	Illumination of the entire virtual scene ranged from high-key lighting (Niedenthal, 2009).	1	Low-key lighting that created a tense atmosphere.
	2	Selection of good colour contrast between the object and the background to ensure good visibility.	2	Dim and dark environments produce fear (Kunstler, 2017).
	3	Dynamic light effects to add realism, such as luminescence or global lighting effects.		
Colour & Texture	4	Fluorescent colours produce a captivating environment and adding high saturation to colours produces more fun (Edge, 2020).	3	Red and green colours to show a tense atmosphere (Mahnke,1996).
	5	Yellow depicts joy and optimistic hope.		
	6	Warm colours depict relaxation and cheerfulness.		
	7	Soft and fuzzy objects create a warm experience.	4	Light that moves with a slow or irregular rhythm.
	8	Down light without bulb with bright lighting.	5	Dynamic light effects that create excitement.
	9	Moving light with a slightly slow rhythm.	6	Placing the light source at an angle that can create shadows.
Effect	10	The light of the lamp follows the outline of the object.		
	11	The light of the lamp fills the plane of the object.	7	Down light.
			8	The light creates a dark silhouette.

This development uses several instruments, including lamps, sky and directional lights, to create an atmosphere that enhances the players' experience. The modeling process prioritizes specific light management techniques as follows:

1. The creation of a bright sky and lighting effects for the exterior sky of the exhibition hall using an additional plugin called Goodsky;
2. Application of God rays or spotlight, using the spotlight type and activation of volumetric cloud features on the exponential cloud;
3. Using blueprint visual scripting, the settings for each desired light mode are configured to prepare moving lights and light transitions.

With respect to these stages, a metaverse environment was successfully created by combining VR technology with highly realistic lighting. This combination resulted in an immersive experience for players who interacted with objects and lighting elements in the East Hall of the Ganesha Campus exhibition space.

7. Lighting Scenario

In the East Hall of the Ganesha Campus, four distinct lighting design scenarios are implemented in the metaverse exhibition space. These scenarios, each exploring the potential emotional impact of positive and negative themes, integrate lighting dynamics with the presented storyline. The main focus is the luminous curved columns that follow the spatial movement and rhythm of the exhibition space design. The sequential arrangement of these columns adds visual dimensions through light outlines framing the arch pillars and serves as a central element guiding the flow of the storytelling light moment. This curated interplay between light and spatial elements communicates messages and emotions to players, establishing it as the main attraction in the exhibition space. Furthermore, the structure of the curved pillars guides the respondents' gaze, facilitating the comprehensive absorption of all information in the exhibition space.

(a) (b) (c) (d)

Figure 5. Across the light spectrum, exploration of four positive and negative lighting scenarios with outline light to express the curved pillars

1. In the first scenario, Limitless Life, the respondents are transported into an environment representing eternity. Figure 5a shows this journey, with yellow outline lights on the curved pillars distinctly depicting the contour details, creating a sharp and exploratory ambiance. The color gradation effect in the binding pillars adds a luminous and carefree touch, similar to navigating through a world of light and joy. However, in darker dimensions, as shown in Figure 5b, green and greyish lighting flashes create a mysterious and boundless atmosphere, presenting a paradox that changes the atmosphere from bright and cheerful to frightening and mysterious.

2. In the second scenario, Mother Spring, the respondents experienced a futuristic adventure. Figure 5c shows a blue environment with a calming aura from the curved pillars, creating a sense of peace and harmony. The starlit and galactic ceiling supports the grandeur of the structure, creating a sensation of being in space. However, in Figure 5d) the red light depicts a sense of tension and unexpected events. The imposing curved column transforms into a mysterious element, triggering a sense of suspense in the light display. In this scenario, the respondents were taken on a confusing and unpredictable journey, presenting a story that explored the duality of human existence, which was full of contradictions and surprises.

The curved column symbolizes strength and charm, maintaining its significance in various lighting conditions. The colored lights it emits react to shifting environments and spatial requirements, creating illusions and immersive atmospheres for those exploring the metaverse exhibition space. This curved column steers the audience's perspectives and imaginations through a journey that illustrates two contrasting design viewpoints: one positive and one negative. The scenarios engage individuals in exploring the lighting space as follows.

a. Exploration of positive lighting in Limitless Life

Figure 6. Positive lighting aesthetics in VR exploration of the Limitless Life exhibition space

Figure 6 shows the light exploration room with sparkling white walls. The deliberate choice of vibrant, candy-like colours contributed to an attractive visual atmosphere. This space depicts a dramatic and eccentric atmosphere, with planet-like objects hovering around the floating stairs. The use of gradient spheres of light further enriches the visual experience by introducing an additional layer of dimensions. Additionally, objects, such as submarines and sharks, are outlined by light-depicted movements in the water, adding another dynamic layer to the exhibition space.

Statues radiating multi-colored light of various shapes create a unique visual experience. Because the light emitted creates a gradient effect, it produces dynamic shadows during motion. Flowers positioned above clouds enhance the aesthetic appeal, while light descending, such as rain, contributes to the illusion of boundless space. Furthermore, the varying intensities at which light is emitted add another dimension, creating a compelling effect on the surrounding elements and enriching the visual narrative.

Misty clouds and moving light lines combine to deepen the respondents' experiences. The mist effect creates a mysterious and dramatic atmosphere complemented by dynamic and futuristic impressions created by the moving light lines. The focus is directed at the head of the statue, illuminated from below to trigger a majestic impression. Moreover, the illuminated eyeglass frames on the lens doubled as screens for displaying exhibition space videos, thus contributing to an enriched and cohesive visual narrative.

b. Exploration of negative lighting in Limitless Life

As shown in Figure 7, a negative lighting design transforms the exhibition space into one with a mysterious atmosphere. In this region, darkness is prominent and draws attention to the illuminated objects in the exhibition space. The infusion of green light creates a cool ambiance in the room. A nocturnal view, in addition to a visible thunderstorm seen through the window, creates a frightening atmosphere. As the respondents ascend the floating stairs, dramatic gradations of light guide their steps, allowing for exploration in the confines of limited movement. The surroundings are

further enriched by balls of blue fiery light, which create a path through a dark hallway-like space.

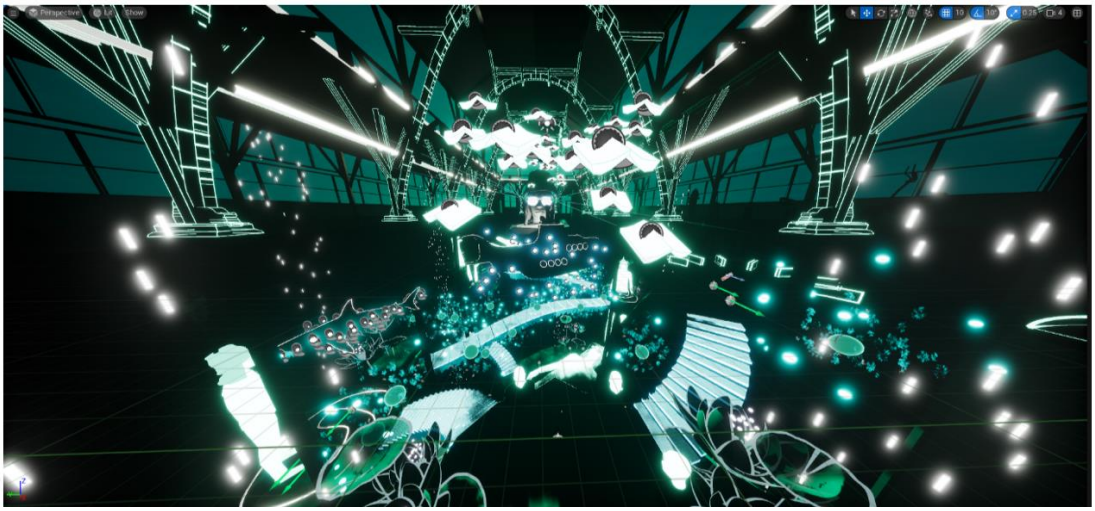


Figure 7. Negative lighting aesthetics in the VR exploration of the Limitless Life exhibition space

The sculptural objects designed by Asmudjo Jono in the exhibition space emanate an intriguing, alternating glow, depicting a mysterious and dynamic presence. The sculptures vary in size and form, featuring both small and large pieces that add a lively element to the environment. The focal point shifts to the head of a large statue, where uplighting highlights glass frames glowing in green, accompanied by the fascinating movement of the emitted lasers. The lenses of the glasses represent a broken video feed, adding a layer of suspense. The submarine and shark objects enhance the theatrical exhibition with their outlined lights revealing spheres of fire that move in response to each motion. This is complemented by bursts of fire from the shark's mouth, while floral objects in the petals offer a subtle and intriguing glimpse. Collections of light depict incessant rain in seemingly limited dimensions. To heighten the drama, a collection of illuminated flying books adds a striking and dramatic touch to this captivating scene.

The presentation of a negative lighting design offered a mysterious visual experience, instilling a sense of fear and hesitation about progressing further owing to restricted visibility. The intentional focus of lighting on individual exhibition objects served to enhance the mysterious atmosphere, eliciting a feeling of wonder and escalating tension as the respondents explored the exhibition space.

c. Exploration of positive lighting in Mother Spring

Figure 8 shows the positive lighting design for the exhibition space, which was used to explore the character of cyberpunk-themed lighting in a dimly lit room with a touch of midnight blue. The lighting design focuses on neon-lit exhibition objects, typical of the digital era, with a calm and comfortable feel when surrounding the entire space. Apart from visual aesthetics, the narrative unfolds through the unique appearance of space and accompanying lighting effects.

The exhibition space is enveloped by trees lined with gradations of light, symbolizing the metamorphosis of human existence. In the middle of the pool, a glowing statue of a mother spills water from a container. Sparkling birds flying overhead illuminate an upward journey with graduated light, revealing a sense of freedom.

Figure 8. Positive lighting aesthetics in VR exploration of Mother Spring exhibition space

The statue's luminous face, aglow with soft blue light and accented by laser effects, dismisses fear. In the pond, the lotus flowers shine brilliantly from bottom to top, basking in a warm spotlight. Sparkling light balls hover above their blossoms, indicating a transformation of self-purification. At the edge of the pond, a waterwheel lined with light rotates, capturing the journey of illumination through a detailed purification process.

d. Exploration of negative lighting in Mother Spring

Figure 9. Negative lighting aesthetics in VR exploration of Mother Spring exhibition space

Figure 9 explores a negative lighting design characterized by a frightening and stunning atmosphere dominated by red hues. The pervasive use of red creates dramatic and dark nuances in the exhibition space. A dimly lit environment creates a mysterious atmosphere that provokes curiosity. The trees surrounding the room are illuminated by alternating bright red clusters depicting dramatic transformations. Fireball lights spread around the trees further enhance the scene by adding an aura of magic and horror.

In the middle of the pond, the statue of a mother is bathed in red light, seemingly releasing luminous droplets similar to rain, symbolizing hope arising from fear,

surrounded by bird lights above it and adding to the scene's ambiance. The statue's head is illuminated by spotlights that expose its texture, thereby positioning the focal point of fear as an exhibition object. In addition to the ongoing tension, the waterwheel is softly coated in red light. The pond is further adorned by line lights outlining the contours of the lotus flowers, contributing to dynamic silhouette effects.

Small points of glowing red light shimmer among the grasses, similar to blood when seen from afar. This creates a somber and mysterious atmosphere that directs the gaze toward the pond. This unique blend of nature and distinctive lighting depicts the energy, lifecycle and spirit of darkness. The tension-filled and unpredictable design of the lighting depicts the boundless nature of change, compelling respondents to explore the inevitable dark side of life.

Asmudjo Jono Irianto's sculptures, renowned for their irony, critique and conceptual depth, were chosen for a VR study to explore the potential of integrating contemporary art with immersive technology. His works, such as "Limitless Life" and "Mother Spring", embody a duality that challenges traditional narratives of art-making through themes of appropriation, critique of artistic norms and reflections on societal roles. This depth made his pieces ideal for reimagining within a metaverse exhibition, where VR could amplify their complexity and contradictions.

In VR, Asmudjo's technical mastery and interdisciplinary approach were brought to life through exaggerated lighting designs and interactive environments. Vibrant, dynamic lighting emphasized the humor and critique in his works, evoking positive emotions like curiosity and joy. Simultaneously, dim, dramatic tones highlighted their more critical and mysterious aspects, fostering tension and reflection. This dual engagement mirrors the paradoxes in his art, allowing audiences to interact with and interpret the sculptures on a deeper, more immersive level. By merging Asmudjo's conceptual artistry with VR technology, the study not only showcased his works but also demonstrated the evolving dialogue between art, critique and contemporary digital innovation".

8. Usability Test and Evaluation

A usability test was conducted using the Oculus Rift S device (Figure 10). The main aim was to understand respondents' responses and perceptions regarding lighting in the metaverse exhibition space. The investigation focused on the modeling features, ambiance and atmospheric lighting in each artwork display.

Evaluation of the respondents' experiences showed that both lighting designs effectively generated responses. Based on the experiments, 57% or 16 out of 28 respondents, felt that positive emotions through the lighting design produced in Limitless Life were more prominent, showing a cheerful and happy mood by featuring a bold display of colors, thereby encouraging respondents to further explore the exhibition. Similarly, 43% or 12 others, felt positive emotions with a peaceful and harmonious mood in Mother Spring, establishing a calm and comfortable atmosphere for users.

Negative lighting designs were effective in capturing the interest of the respondents for further interaction. 36%, or 10 respondents, agreed that Limitless Life had more prominent negative emotions, with the dark ambiance introducing tension and instilling a fear of falling due to poor visibility. Considering Mother Spring, 18 respondents felt strong negative emotions with the red lighting model creating a sense of oppression and

fear, specifically with detailed textures at the head of the statue, making it eerie and captivating.

Figure 10. Usability test with evaluating players experiencing the metaverse exhibition lighting modeling products using VR devices

This study highlights the importance of emotional valence as the main factor in understanding the effects of lighting. Positive lighting, characterized by brightness, diversity and low color temperatures, served as a catalyst, motivating respondents to actively explore the exhibition space. It also represents strong emotional responses, creating an atmosphere that stimulates the respondents' enthusiasm to interact with and engage with the exhibition. Meanwhile, negative lighting, marked by dimness and low color temperature, reduced the respondents' interest in further exploration.

The effective use of VR technology enhanced the respondents' overall experience through physical activity data. VR is a powerful tool for stimulating sensory experiences, positively influencing perceptions of both lighting and the general exhibition atmosphere. The evaluation results clearly show the crucial role of lighting in shaping respondents' experiences in the metaverse exhibition space. The distinction between positive and negative lighting designs substantially impacted emotional responses and influenced the respondents' interest in interacting with the space.

9. Conclusion

The interplay between negative and positive lighting designs offers a profound narrative about the dualities of human experience - fear and hope, darkness and light, tension and serenity. The negative lighting design immerses viewers in an atmosphere charged with dramatic red hues and shadowy nuances, creating an environment that provokes curiosity and confrontation with fear. The dim lighting, punctuated by glowing red clusters and fireball lights, evokes supernatural tension, symbolizing the darker, unpredictable side of life. At the heart of this haunting scene, a statue of a mother, bathed in red light and releasing luminous droplets, becomes a poignant symbol of hope arising from fear. Surrounding elements - glowing grasses, silhouetted lotus flowers and a softly lit waterwheel - further deepen the narrative of transformation and the inevitability of change. In contrast, the positive lighting design shifts the emotional tone, bathing the space in calming midnight blues and vibrant neon accents. Here, the cyberpunk aesthetic transforms the same elements into symbols of renewal and progress. The glowing statue, spilling water under soft blue light, represents serenity and the dismissal of fear, while sparkling birds overhead guide the gaze upward, embodying freedom and aspiration. The luminous lotus flowers and rotating waterwheel celebrate the journey of self-purification

and enlightenment, creating a space where transformation feels uplifting and boundless. Together, these designs convey a powerful story of the human condition. The negative lighting reflects the tension-filled, shadowy paths we must sometimes navigate, while the positive lighting offers a vision of transcendence and growth. The juxtaposition highlights the transformative power of light, not only as an aesthetic tool but as a medium that shapes emotional and psychological experiences, bridging the boundaries between fear and hope, darkness and light illumination.

This study utilized exaggerated lighting design and VR technology to elicit emotional responses, identifying positive and negative valences as key themes. Positive lighting, with brightness, rich colors and high color temperatures, encouraged exploration, while negative lighting, defined by dimness and low color temperatures, created tension and reduced engagement. Lighting effectively guided respondents' emotions and attention, playing a vital role in crafting immersive and impactful metaverse exhibition experiences. By enhancing the sense of presence and connection, the integration of lighting and VR significantly shaped respondents' interactions and emotional responses.

References

Adharamadinka, M., Junaidy, D.W. (2023). Spatial mental imagery gap of student-studio lecturer and client-designer/architect by virtual reality and non-virtual reality. *Education and Information Technologies*, *28*(7), 8607-8643. https://doi.org/10.1007/s10639-022-11534-2

Akay, S. (2022). Lighting for tension in video games. Master's thesis, KTH, School of Architecture and the Built Environment (ABE), Architecture, Lighting Design.

Belk, R.W. (2013). Extended self in a digital world. *Journal of Consumer Research*, *40*(3), 477-500. https://doi.org/10.1086/671052

Bruun, A., Stentoft, M.L. (2019). Lifelogging in the wild: Participant experiences of using lifelogging as a research tool. In *IFIP Conference on Human-Computer Interaction*, 431-451. https://doi.org/10.1007/978-3-030-29387-1_24

Cornelio, P., Dawes, C., Maggioni, E., Bernardo, F., Schwalk, M., Mai, M., ... & Obrist, M. (2022). Virtually tasty: An investigation of the effect of ambient lighting and 3D-shaped taste stimuli on taste perception in virtual reality. *International Journal of Gastronomy and Food Science*, 30, 100626. https://doi.org/10.1016/j.ijgfs.2022.100626

Deterding, S., Sicart, M., Nacke, L., O'hara, K. & Dixon, D. (2011). Gamification. using game-design elements in non-gaming contexts. In *CHI'11 Extended Abstracts on Human Factors in Computing Systems*, 2425-2428.

Edge (2020). *Arise: A Simple Story*. Bath, UK: The Future of Interactive Entertainment, 112-113.

Ellsworth, P.C., Smith, C.A. (1988). Shades of joy: Patterns of appraisal differentiating pleasant emotions. *Cognition & Emotion, 2*(4), 301-331.

El-Nasr, M.S. (2004). Utility of automatic lighting design 3-D virtual training environment. https://apps.dtic.mil/sti/pdfs/ADA433295.pdf Accessed on 10.01.2024.

Few, S. (2006) *Information Dashboard Design: The Effective Visual Communication of Data*. O'Reilly Media.

Fonnet, A., Prié, Y. (2019). Survey of immersive analytics. *IEEE Transactions on Visualization and Computer Graphics*, *27*(3), 2101-2122. https://doi.org/10.1109/TVCG.2019.2929033

Garner, T., Grimshaw, M. (2011). A climate of fear: Considerations for designing a virtual acoustic ecology of fear. In *Proceedings* of *the 6th Audio Mostly Conference: A Conference on Interaction with Sound*, 31-38.

González-Martín, C., Carrasco, M. & Oviedo, G. (2022). Analysis of the use of color and its emotional relationship in visual creations based on experiences during the context of the COVID-19 pandemic. *Sustainability*, *14*(20), 12989. https://doi.org/10.3390/su142012989

Graja, S., Lopes, P. & Chanel, G. (2020). Impact of visual and sound orchestration on physiological arousal and tension in a horror game. *IEEE Transactions on Games, 13*(3), 287-299. https://doi.org/10.1109/TG.2020.3006053

Henz, P. (2022). The societal impact of the Metaverse. *Discover Artificial Intelligence, 2*(1), 19. https://doi.org/10.1007/s44163-022-00032-6

Isbister, K. (2016). *How Games Move Us: Emotion by Design*. Cambrdige: MIT Press.

Jicol, C., Wan, C.H., Doling, B., Illingworth, C.H., Yoon, J., Headey, C., … & O'Neill, E. (2021). Effects of emotion and agency on presence in virtual reality. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 1-13. https://doi.org/10.1145/3411764.3445588

Junaidy, D.W., Adharamadinka, M., Kusumah, G.K., Darmakusuma, R., Ginalih, C.T., Sakya, K.A. & Mawali, L. (2024). Examining the spatial perception of users of verbally generated 3D virtual space visualizations. *Archives of Design Research, 37*(1), 61-83.

Kauppinen-Räisänen, H., Luomala, H.T. (2010). Exploring consumers product-specific colour meanings. *Qualitative Market Research, 13*(3), 287-308. https://doi.org/10.1108/13522751011053644

Kaya, N., Epps, H.H. (2004). Relationship between color and emotion: A study of college students. *College Student Journal, 38*(3), 396-405.

Kim, D.H., Mansfield, K. (2021). Creating positive atmosphere and emotion in an office-like environment: A methodology for the lit environment. *Building and Environment*, 194, 107686. https://doi.org/10.1016/j.buildenv.2021.107686

Kong, Z., Liu, Q., Li, X., Hou, K. & Xing, Q. (2022). Indoor lighting effects on subjective impressions and mood states: A critical review. *Building and Environment*, 224, 109591. https://doi.org/10.1016/j.buildenv.2022.109591

Kuller, R., Ballal, S., Laike, T., Mikellides, B. & Tonello, G. (2006). The impact of light and colour on psychological mood: A cross-cultural study of indoor work environments. *Ergonomics, 49*(14), 1496-1507. https://doi.org/10.1080/00140130600858142

Kunstler, J.H. (2017). *Atmosphere: The Seven Elements of Great Design.* New York, Grove Press.

Li, Y., Ru, T., Chen, Q., Qian, L., Luo, X. & Zhou, G. (2021). Effects of illuminance and correlated color temperature of indoor light on emotion perception. *Scientific Reports*, 11, 14351. https://doi.org/10.1038/s41598-021-93523-y

Mahardika, M.S., Junaidy, D.W., Gary, A.A.P., Husni, E.M., Suwardhi, D., Agirachman, F.A., … & Wibisono, A. (2023). Preserving history in the metaverse: A platform to digitize the campus cultural heritage in Indonesia. *ISVS-e Journal, 10*(12), 626-645.

Mahnke, F.H. (1996). *Color - Environment and Human Response.* New York, Van Nostrand Reinhold.

Niedenthal, S. (2009). Patterns of obscurity: Gothic setting and light in Resident Evil 4 and Silent Hill 2. In *Horror Video Games: Essays on the Fusion of Fear And play*, 168-180.

Perron, B. (2005). A cognitive psychological approach to gameplay emotions. In *Proceedings of DiGRA 2005 Conference: Changing Views - Worlds in Play*, 1-10.

Plutchik, R. (1982). A psychoevolutionary theory of emotions. *Social Science Information, 21*(4/5), 529-553. https://doi.org/10.1177/053901882021004003

Quinn, R.E., Rohrbaugh, J. (1981). A competing values approach to organizational effectiveness, *Public Productivity Review, 5*(2), 122-140. https://doi.org/10.2307/3380029

Russel, W.B. (1980). Review of the role of colloidal forces in the rheology of suspensions. *Journal of Rheology, 24*(3), 287-317.

Ryandi, A.K. (2023). Designing an exhibition space based on exaggeration in the metaverse. Faculty of Art and Design, Bandung Institute of Technology, Indonesia. (In Indonesian).

Skarbez, R., Brooks Jr, F.P. & Whitton, M.C. (2018). Immersion and coherence in a stressful virtual environment. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*, 1-11. https://doi.org/10.1145/3281505.3281530

Steinhaeusser, S.C., Oberdörfer, S., von Mammen, S., Latoschik, M.E. & Lugrin, B. (2022). Joyful adventures and frightening places–designing emotion-inducing virtual environments. *Frontiers in Virtual Reality*, 3, 919163. https://doi.org/10.3389/frvir.2022.919163

Yoo, S., Gough, P. & Kay, J. (2018). VRFit: An interactive dashboard for visualising of virtual reality exercise and daily step data. In *Proceedings of the 30th Australian Conference on Computer-Human Interaction*, 229-233. https://doi.org/10.1145/3292147.3292193

Zhang, Y., Liu, H., Kang, S.C. & Al-Hussein, M. (2020). Virtual reality applications for the built environment: Research trends and opportunities. *Automation in Construction*, 118, 103311. https://doi.org/10.1016/j.autcon.2020.103311