

EXPLORING THE USES OF INTERACTIVE HOLOGRAMS
IN LIVE ENTERTAINMENT

by

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ABSTRACT

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Master of Digital Media, 2023

Digital Media

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The entertainment industry has always been at the forefront of technological innovation while it constantly redefines its creative boundaries. The introduction of interactive digital technologies brings exciting possibilities into the field, particularly in live performances. This project studies holograms as a critical technology that sets trends in future live event design due to its unique characteristics and deeper philosophical implications. The project begins with a thorough study of the various types of holograms, their historical contexts, operations, strengths and limitations, and suggestions for future applications. Existing interpretations of holograms are analyzed next, focusing on identifying the gaps in knowledge on their applications. The research raises insightful questions on the significance of using hologram technology for entertainment and illustrates possible effects it could achieve through a variety of visual and experiential prototypes. As part of the final product, a systematic workflow is presented in the form of infographics that guide designers and content creators through a seamless process of incorporating holograms into live events programming. The project demonstrates the potential of holograms in substantially reshaping modern entertainment, offering a sustainable prospect for interactive digital technologies to augment in-person event experiences.

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1. INTRODUCTION

1.1 Research Question

Over the past century, the global media and entertainment industry has been continuously reforming at a fascinating rate. Within this scope, live entertainment is one of its fastest growing sectors today, estimated to reach a total revenue of US\$68.7 billion in 2024 [Figure 1.1] (PwC, 2023). The arrival of the COVID-19 pandemic has brought the most tremendous challenges in its recent history: as perceptions of group activities, physical space and in-person communication are drastically reshaped, the live entertainment landscape is in dire need of a typology that adequately meets the demands of the post-pandemic era (Mair and Smith, 2021).

In this project, interactive hologram technology is introduced as an ideal solution to this pressing issue. The following research investigates how responsive hologram illusions could revolutionize live entertainment by offering new modes of artistic expression and enhancing audience engagement. By delving into its technological, social, and psychological aspects, the research aims to explore the technology's ability to breathe new life into traditional forms of performances and elevate participants' experiences to unprecedented heights.

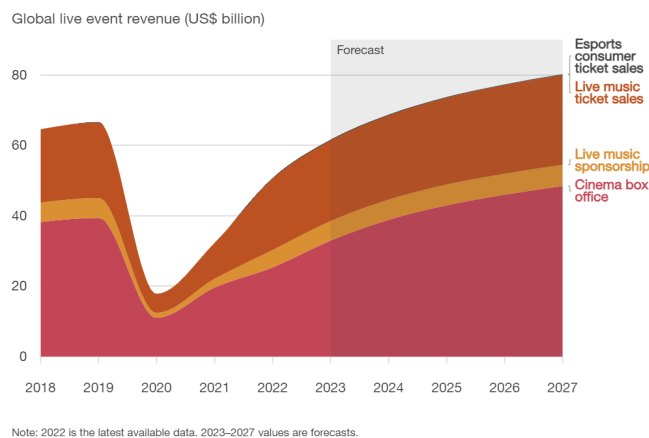


Figure 1.1a: Projection of live entertainment industry revenue in US \$ billion
(Image source: PwC's Global Entertainment & Media Outlook 2023-2027, Omdia)

1.2 Concept Definitions

In order to convey the project findings and theories in the most accurate and effective manner, the following key terms are defined within the context of this research paper.

Live entertainment refers to any activity that engages multiple participants simultaneously within a physical space; it requires the audience to be at a specific location for a fixed amount of time to consume the performance, event, or presentation in real-time (Cameron, 2006). Possible forms of live entertainment include, but are not limited to: concerts, dance performances, plays, fashion shows, exhibitions, and sports events. These events are characterized by the spatio-temporal co-presence they provide to their participants, where content is defined and interpreted within the context of a togetherness (Samek, 2021).

Hologram technology is a technique that creates the appearance of 3D objects floating in space. Essentially, it is a two-dimensional representation or imitation of a hologram's appearance, giving the impression of a three-dimensional object by utilizing specialized surfaces and projection techniques [Figure 1.2a] (Berry, 2022). The resulting images – referred to as *holograms* – present realistic and immersive visual illusions of solid objects or lifelike figures suspended in space, visible to the naked eye without the need for additional devices [Figure 1.2b]. In this study, the term *hologram* is often used interchangeably with *holographic projection*. This concept is not to be confused with *holography*, a genuine 3D imaging technique that records and reconstructs the full three-dimensional information of an object or figure [Figure 1.2c] (Haleem et al., 2022). The process of holography involves the use of laser light to record and reconstruct the complex interference patterns of light waves scattered from an object (Respecher, 2021). Holography is used as a niche but valuable tool in scientific research and industrial applications, such as holographic surface metrology, microscopy, and data storage, but is less commonly applied in entertainment contexts (Haleem et al., 2022).

In addition, it is important to note that the hologram technology being discussed here is fundamentally different from most science-fiction portrayals of “holograms” [Figure 1.2d]. In science fiction, holograms are often depicted as fully-formed, interactive 3D projections floating in mid-air without the need for any physical medium or screen. Unfortunately, this has never been accomplished in real-life as there is no effective way for photons to remain at designated positions by themselves (Hall, 2018). Even if it were to be created in the future, it would align more closely with holography than the hologram technology being discussed in this paper. Although the holograms ambitiously depicted in science fiction are not currently achievable, existing applications of hologram illusions in entertainment have already illustrated their effectiveness in captivating audiences, hence they are the object of focus in this paper.

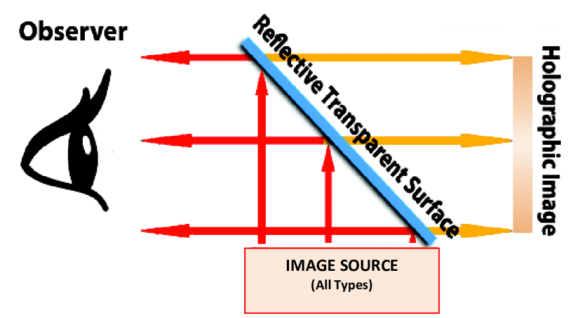


Figure 1.2a - Illustration of *hologram illusions*
(Source: Yasser El-Gammal)

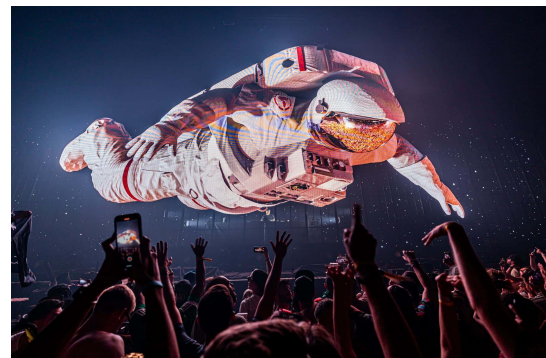


Figure 1.2b - Hologram illusions at Swedish DJ Eric Prydz's HOLO music event
(Source: Eric Prydz's Twitter)

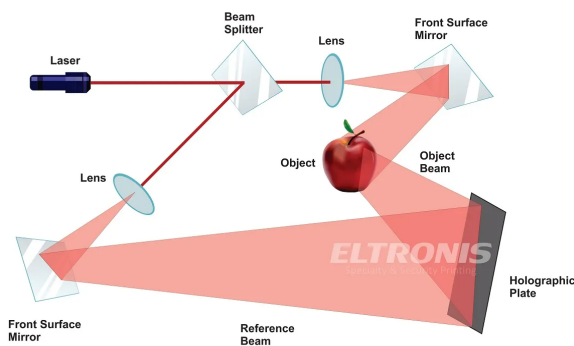


Figure 1.2c - Illustration of *holography*
(Source: Eltronis)

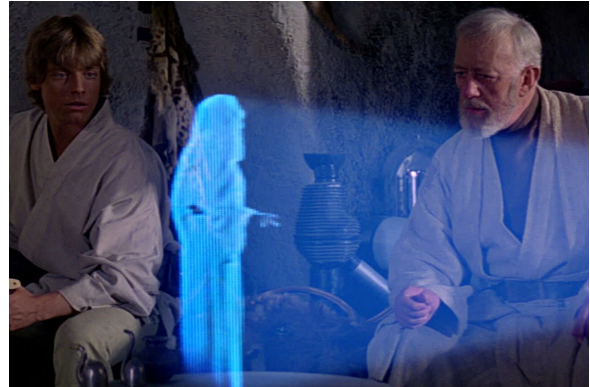


Figure 1.2d - Princess Leia Hologram in *Star Wars*
(Source: starwars.com)

Interactivity (in digital media) refers to the degree of engagement and two-way communication between users and a presented system, application, or interface (Troseth et. al., 2019). It reflects the system's capacity to receive input from users in various forms, including taps, voice commands, or gestures, and to respond with perceptible outputs, such as movement, light, or sound, in real-time. In live entertainment settings, specifically, interactivity represents the ability for the audience to affect how content is perceived.

2. CONTEXT & SIGNIFICANCE

2.1 Historical Development

a. Live Entertainment

The history of live entertainment dates back to ancient civilizations, reflecting the deeply rooted human desire for communal gatherings and shared leisure experiences. Live music first began to take on a key cultural role in Ancient Greece and Rome periods, customarily appearing at cultural ceremonies, social events, and theatre performances (Petronio, 2020). In the 8th century BC, the creation of the first Olympics games offered a significant opportunity for cultural exchanges and interactions while consuming the same content (Schaus and Wenn, 2007). Overtime, as religions became increasingly important globally during the Medieval Era, live performances further infiltrated society through public chants and music that accompanied religious services (Petronio, 2020). During the 15th and 16th centuries, the establishment of permanent playhouses across Europe marked a significant advancement in theatre performances; renowned playwrights during the Renaissance, such as William Shakespeare and Christopher Marlowe, contributed immensely to the rise of live theatre (Anderson, 1991). It was this time period that live performances started to hold emotional and social significance, where watching plays was viewed as a means by which “the spectator could leave the time and space of everyday life in order to occupy an ideal dimension” (Costola, 2009).

A diverse range of group entertainment emerged throughout the 19th-century, including sports games, music halls, and circuses, catering to audiences of varying social statuses and preferences (Lambert, 2021). By the 20th century, live entertainment gained even broader reach and impact with the inventions of electronic communications, namely the radio and the television (Kurin, 2017). Consequently, live broadcasts of concerts, theater plays, and sporting events

became popular, further cementing live entertainment consumption as an essential part of culture that brings people together (World Financial Review, 2021). Entering the Digital Age – beginning around the 1970s – the global live entertainment sector has continued to reach new heights with the evolution of the internet and social media. From electrifying music concerts and theatrical performances to interactive virtual events and live-streamed spectacles, live entertainment continues to push boundaries, offering innovative ways to unite diverse audiences and consume entertainment content (World Financial Review, 2021).

Throughout its rich history, despite the style, scale, and technicality involved, audience engagement has remained the focus of all live entertainment. With new means of digital communication being developed, including the advent of the Internet, social media platforms, and advanced entertainment devices, the essence of the industry will continue to be the ability to resonate with viewers, listeners, and participants on emotional and sensory levels.

b. Hologram Technology

The usage of holograms in live entertainment traces back to the 1860's with the creation of the Pepper's Ghost illusion, an effect involving an angled reflective surface and strategically positioned light to cast a translucent image of an actor or stage prop hidden from the audience onto the stage [Figure 2.1a] (MacNeal, 2022). Named after John Henry Pepper, a 19th century British scientist and showman, the Pepper's Ghost effect found its way into various entertainment formats soon after its development, including amusement parks, theaters, and magic shows, as an illusionary trick (MacNeal, 2022).

As technologies continued to advance over the century, hologram illusions have achieved increasingly higher levels of realism while playing an integral role in live entertainment.

Although the basic concept of replicating an object in a displaced environment using two-dimensional projections remains the essence of most hologram illusions today, processes of designing and producing such effects have become entirely digitalized in recent years (Ngak, 2012). One of the most well-known instances of its usage in modern live entertainment was the holographic appearance of Tupac Shakur at the 2012 Coachella music festival, where a lifelike moving image of the late rapper performed alongside Dr. Dre and Snoop Dogg, leaving audiences in awe [Figure 2.1b] (Ngak, 2012). Since then, hologram illusions have been applied more commonly at live events in varying scales and styles. Additional examples will be examined in Section 2.5: Case Studies of Holograms in Entertainment.



Figure 2.1a - Pepper's Ghost Effect
(Source: Magic Halo)



Figure 2.1b - Tupac's Hologram at Coachella 2012
(Source: CNN)

2.2 Industry Trends

With the introductions of digital technologies into the landscape, online live entertainment has soared in popularity since the turn of the century (Davies, 2023). This trend became remarkable in Spring 2020, when the COVID-19 pandemic caused temporary shutdowns

or restrictions of gatherings around the world. The pandemic accelerated the adoption of digital solutions, leading to a surge in virtual gatherings and live-streamed performances (Swarbrick et al., 2021). As revealed by a MIDiA Research study, the listings of live-streamed concerts on music website Bandsintown grew from 1.9% in June 2020 to 40.7% by November (Davies, 2023). Overall inclusivity and accessibility of the industry has increased significantly as a result, where artists and content creators have embraced new mediums to reach global audiences, break down geographical barriers and access new revenue streams. These virtual mediums are creating new structures of entertainment, leveraging digital tools to exceed existing expectations. For instance, Coachella 2022 used Unreal Engine 5 to add augmented reality overlays of visual effects during its YouTube livestream, offering distinct in-person and online variations, with digital tools making each version uniquely appealing [Figure 2.2a] (Chow, 2022). It has also prompted adaptations in ways to connect with audiences under special circumstances, broadening the scope of the industry.

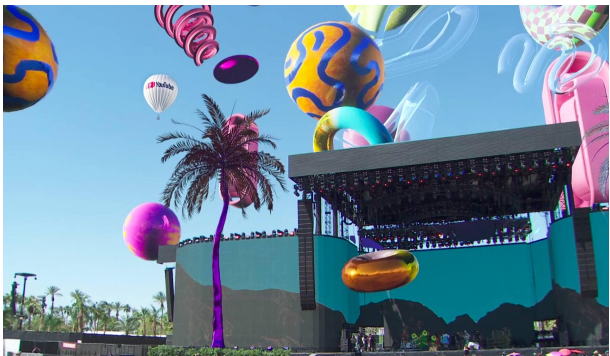


Figure 2.2a - AR overlays in Coachella 2022's YouTube livestream
(Source: Goldenvoice LLC)

On the other hand, in-person live entertainment has also seen a resurgence since global restrictions have gradually been lifted throughout 2022. While other branches of entertainment have suffered heavier losses, live performances are bouncing back sooner due to its unique focus

on the relationship between audience members and performers. The concert industry is experiencing an unprecedented surge in popularity, with superstars like Beyoncé and Taylor Swift who are on their way to break the \$1 billion mark and break the world records for the highest-grossing tours of all time (Malleck, 2023). Many believe that digital alternatives cannot fully replace this experience of – and considered less “worthy” than – being in the same physical space as the celebrities presenting the content (Ryu & Cho, 2022). Furthermore, modern audiences are showing that “at a time when connection is more sought-after than ever, [they wish to get ...] a sense a close-knit community they crave” (United Talent Agency, 2021). Hence, although audiences are attending gatherings remotely, they are brought together by a sense of social connection, making it stand out once more as the core value of live entertainment regardless of form (Swarbrick et al., 2021).

The virtual events space is still expected to expand by about 25% over the coming decade, indicating that digital communications will remain an integral part of the live entertainment landscape after COVID-19 (Jain, 2022). Yet, while benefits of online platforms, such as allowing personal control over content and additional effects unbound by spatial restraints are evident, the relationship building and participant engagement at in-person events are difficult to replicate virtually (Jain, 2022). Thus, virtual connections and in-person events soon stopped being regarded as opposing typologies, but components to be merged for optimized entertainment experiences. Hybridizations that blend virtual and physical elements have emerged as a powerful trend, allowing organizers to offer diverse entertainment experiences that accommodate varying demands while preserving the unique immersiveness of shared physical gatherings (Frankfurt, 2022). Flexibility is a central advantage offered by this new typology, where “utilizing the right kind of digital tools can both recreate the in-person experience for

those not in attendance while enhancing the experience for those showing up in person” (Frankfurt, 2022).

In particular, the incorporation of interactive technologies is becoming more prominent in supporting live entertainment. Attendees can participate in defining the experience through real-time controls, achieving a degree of convenience similar to consuming virtual content while experiencing involvement within a physical gathering. Collective interactivity, specifically, is guiding the direction in which future live entertainment is heading towards. The following section examines the concept in further detail.

2.3 Interactivity In Entertainment

In recent decades, new forms of entertainment have developed, shifting the audience’s role from passive consumers to active participants on the interactive spectrum. Even after the COVID restrictions have lifted, the enduring popularity of online services highlights modern audiences' strong preference for personalized and engaging entertainment experiences. Jose Tolosa, CEO of American arts and entertainment company Meow Wolf, points out that *“storytelling entertainment has traditionally been a linear, non-interactive experience where audiences passively consume what a corporate entity curates for them”*, but this paradigm is set to change with the arrival of interactive entertainment (McGowan, 2022). In the realm of live entertainment, interactivity enhances the user experience by enabling active engagement and customization, empowering individuals to shape the environment according to their preferences and needs. As an example of an interactive entertainment experience, participatory theatre “Sleep No More” invites viewers to become a key part of the performance by including them within the story plot, where each show varies slightly depending on the response of the individual

audiences [Figure 2.3a] (Woltmann, 2023). Here, interactivity serves as the gateway for attendees to not only influence the content, but also to feel a stronger sense of presence in the event, validating their active role in the experience (Woltmann, 2023).



Figure 2.3a - Participatory theatre *Sleep No More*
(Source: Lucas Jackson | Reuters)

The interactive entertainment sector is viewed as the ambitious synthesis of technology and creative arts. While its technological foundation fuels rapid advancements, its creative essence drives continuous innovations in storytelling and expressive methods (Medium, 2018). With interactive technologies shaping the future of live event programming, there is a growing focus on *synaesthetic performances*, which incorporate live audience inputs and translate them into visual or audio effects (Shirzadian et. al., 2018). The act of simultaneously participating in actions that are immediately reflected within the performance has been shown to cultivate a stronger emotional sense of “togetherness” within the audience, adding layers of significance to the live event experience (Shirzadian et. al., 2018). Moreover, interactivity enhances immersiveness, delivering dynamic and shareable content that cannot be replicated at home (McGowan, 2022).

Over the coming decades, industry experts anticipate the rise of hybrid live events that use digital tools to create more interesting experiences and simultaneously encourage

communication across in-person as well as virtual platforms (Chow, 2022). The academic discourse on the convergence of physical and digital realms has gained momentum in recent years, with the resurgence and redefinition of the term *Metaverse* by Mark Zuckerberg in 2021 being a pivotal moment in this evolution (De Felice et. al., 2023). Scholars are increasingly exploring how the integration of digital technologies within physical spaces is reshaping various aspects of human experiences, including entertainment, communication, and social interactions (Chow, 2022). A recent illustration of this trend is Coachella 2023, where attendees accessed AR portals scattered throughout the festival to unlock exclusive social media filters inspired by American singer Becky G's makeup line (Carlton, 2023). By blending virtual features with the physical environment, Coachella participants engage in a broader narrative, extending their influence beyond the event's physical boundaries while retaining control over the methods and extents of which they wish to interact with the available content [Figure 2.3b].



Figure 2.3b - Coachella 2023's AR environment
(Source: Coachella)

Holograms serve as a powerful medium for creating immersive experiences within physical spaces. While the majority of hologram illusions in live entertainment settings today are pre-rendered digital visualizations projected onto a screen, resembling a video playback, their true potential lies in becoming responsive to audience behavior (Rowell, 2019). Their highly realistic appearances and visibility to the naked eye offer promising opportunities for interactive holographic effects to captivate audiences in more immersive storytelling.

2.4 Literature Review

To illustrate how interactive holograms could enrich the future of live themed entertainment, it is essential to evaluate the existing knowledge in the field. While its formats have altered throughout history, live entertainment has often been discussed for its unique social and emotional impacts on its participants. Cameron's 2006 article delves into the psychology of live entertainment, stating that a unique live experience is shaped by various factors such as lighting, ambience, audience atmosphere, and presented content (Cameron, 2006). Unlike pre-recorded or online events, live entertainment inherently involves additional anticipation and/or resistance due to the element of time and unfiltered emotions within participation (Cameron, 2006). Furthermore, Berkers and Michael highlight the essence of in-person entertainment with the concept of *collective effervescence*, wherein individuals in the audience interact and form a shared identity similar to in religious practices (Berkers & Michael, 2017).

These energy levels and social cohesions last far beyond the event's conclusion, and they are established upon a mutual focus of attention and emotional experience. These events require the audience to be physically present in a designated location for a certain length of time, and this bodily co-presence "is a necessity [...] in contemporary mediatised society", where the rise

of online entertainment is contributing to an emotionally distanced era (Berkers & Michael, 2017). Moreover, live entertainment also contains an irreplaceable value of bringing audience members into the same physical space as the performers. The proximity to the artists or performers elevates the experience, adding a higher emotional and symbolic significance than the mere consumption of content (Ryu & Cho, 2022). The emphasis of existing literature on the perceptual and emotional aspects of defining live entertainment, rather than imposing harsh constraints on its material characteristics, has been key in enabling the industry to welcome the arrival of new technologies and continuously become diversified.

Traditionally, “media users are consistently considered merely witnesses of the events they perceive during exposure”, with a basic assumption in media content design that they are not capable of influencing the narrative they are presented with (Vorderer et. al., 2001). However, the ascent of new online media forms in recent years, such as narrative games, has revealed society’s growing desire for control over their entertainment content (Williams, 2023). This inclination is also influencing offline activities, elevating people's expectations for in-person events. No longer content with passive consumption, individuals now seek to actively engage and participate in the live experience, becoming integral contributors to the event (Samek, 2021).

In live entertainment events that hold specific spatio-temporal contexts, the use of digital tools to facilitate interactivity is gaining popularity and significance. As the audience engages with the event through voice commands, bodily movements, or operating mobile devices, they actively create meaning and build connections within the event space, as well as with fellow attendees (Trunfio et. al., 2022). These interactive elements play a crucial role in fostering emotional relationships between the audience and the entertainment content, which is a significant aspect of the overall entertainment experience (Vorderer et. al., 2001). Moreover,

attending in-person events is often socially driven, with audience members bonding over shared emotional experiences and synchronous movements, creating a sense of togetherness that can be challenging to achieve in virtual gatherings (Swarbrick et al., 2021).

Virtual technologies have demonstrated their effectiveness in enabling visitors to personalize their experiences by exerting conscious control over the content they view. But device or screen-based activities, including VR and AR technologies, have faced criticism when used in live performance settings due to their potential to distract the audience from the actual performers or presented content (Samek, 2021). Vorderer discusses the ability for interactivity to strengthen audience engagement in relation to their capabilities to stay focused on the presented content rather than being sidetracked by the actions required to participate in it (Vorderer et.al., 2001). As such, it is necessary in future applications to carefully decipher the fine line between audience engagement and distraction, ensuring that the immersive technologies enhance the overall experience without detracting from the intended focus of the live performance (Samek, 2021).

There exists other large-scale screen-based technologies that merge art and technology seamlessly to ensure audience engagement instead of diversion, exemplified by new media artist Refik Anadol's LED data sculptures (Vankin, 2023). By employing Artificial Intelligence to convert data and images into dynamic sequences within the installation frame, these sculptures create remarkably realistic and captivating visual experiences that enhance architectural spaces they exist within (Vankin, 2023). However, as they are confined to the two-dimensional surface of the LED screen, they introduce distinct visual separations between the artistic effect and the immediate physical environment (Vankin, 2023). The use of hologram illusions presents a fine solution to address these concerns simultaneously, as it eliminates the need for a physical screen,

thus reducing the risk of distraction while still delivering realistic, three-dimensional visual experiences. Holographic projections are able to create a visual presence without a tangible form, seamlessly integrating into the viewer's reality, instead of drawing viewers into the isolated virtual spaces as in Virtual Reality (Ng, 2021). Coexisting with the physical surroundings, holograms also help maintain the audience's connection and attention to the live event and fellow attendees.

Throughout history, many conversations about hologram effects remain philosophical and conceptual. Appearing to occupy a three-dimensional space, its unique visual representation sparks conversations about the displacement and the representation of a physical presence, inspiring creators and viewers to question what is "real", and what is merely "visible" (Barcellos and Junior, 2015). Although the hologram technology discussed in the context of this paper is more about creating the *illusion* of a three-dimensional being, its levels of realism have been enough for it to spark philosophical questions about “reality”.

In the mid-20th century, scientist David Bohm proposed the intriguing theory that the world operates similarly to a hologram, generating representational images from a fundamental level of truth (Barcellos & Junior, 2015). This concept has long been a popular theme in science fiction, exploring the distinction between material reality and visual presence (Barcellos & Junior, 2025). The potential of holograms to create visual representations of truth has led to their exploration in various fields, such as healthcare. For instance, a research project conducted by Aspen Medical Group in 2022, titled "Can Hologram Technology Promote Family Connection and Combat Anxiety and Depression in Oil and Gas Employees," investigated the technology's ability to provide therapeutic effects by projecting real-life images remotely (Valdez & Jeremijenko, 2022). In this case, hologram illusions are professionally used as a substitute for a

physical presence, indicating their potential to create realistic visual experiences that can evoke emotions and "trick" the mind.

Due to these unique characteristics, there have been more considerations in its applications than other XR technologies. The academic discussions focused on dissecting its history and metaphorical intentions rather than projecting its technical potential has largely caused the narrowness of its interactive applications. When the holograms involve real humans, more legal and moral procedures need to be carried out to ensure ethical industry practice, and avoid problems such as portrait rights and copyrights (Marinkovic, 2021).

In terms of its interactivity, although products such as the Microsoft HoloLens now allow gesture and voice commands to alter visualizations in real time, further “anthropometrical and ergonomic [considerations are required to ... enable] the necessary hyper-realism, interaction, at the exact moment of projection" of holograms visible to the naked eye (Barcellos and Junior, 2015, pg 760). Moreover, while use cases of other interactive digital technologies are also being examined for the post-event effects they cast on visitors, such as creating long-lasting impressions, there is a lack of such examination around holograms, as it is studied for its visual impact only at the time of viewing. Since holographic projections focus on visually replicating an existing object or person, current metrics of evaluations also revolve mainly around how accurately they capture and recreate the details of the “original image”, instead of its capabilities to construct narrative immersive experiences. To expand its usage in the entertainment industry, further studies on its storytelling methods need to be carried out, specifically how it could respond to real-time cues to bring interactive content.

2.5 Case Studies: Holograms in Entertainment

a. Hatsune Miku

Hatsune Miku is a virtual pop star created by Japanese technology firm Crypton Future Media in 2007 (Marchand, 2020). Launched as the mascot character to demonstrate the capabilities of a voice synthesizer software, her signature turquoise pigtails, enthusiastic “personality” and dynamic song choices have gradually established a global fanbase for her [Figure 2.5a] (Marchand, 2020). Since her debut, she has released more than 100,000 songs, “collaborated” with celebrities such as Pharrell Williams and Lady Gaga, and appeared at significant music festivals, including Coachella in 2020 (Rehagen, 2021).

Through the use of Pepper's Ghost technique, Miku is brought to life on stage as a holographic projection, seamlessly interacting with a live band and the audience [Figure 2.5b] (Marchand, 2020). Choreographed with mesmerizing visual stage effects and live music, her concerts showcase the powerful fusion of technology, creativity, and fandom in the new era of live entertainment. Considered the world’s most popular virtual celebrity, she has performed in over 40 concerts, some of which have drawn massive crowds of more than 4,000 attendees. (Machkovech, 2016). Hatsune Miku's success has highlighted the transformative potential of hologram technology, demonstrating how it could turn virtual characters into cultural icons that can captivate live audiences.



Figure 2.5a - Hatsune Miku (Source: Canada Newswire)



Figure 2.5b - Hatsune Miku in concert (Source: Crypton Future Media)

b. Michael Jackson's Holographic Performances

In 2013, Cirque du Soleil unveiled an awe-inspiring holographic tribute to the King of Pop, Michael Jackson, during their "Michael Jackson ONE" show in Las Vegas (Greenburg, 2013). The performance featured a stunningly realistic representation of the late music legend, dancing and singing alongside live performers on stage before eventually “evaporating” at the end of the song (Greenburg, 2013). In 2014, Michael Jackson's holographic projection made a stunning return during the Billboard Music Awards performance of "Slave to the Rhythm", accompanied by a talented five-piece band and 16 dancers [Figure 2.5d] (Gallo, 2014). To ensure the hologram's success, a specially designed stage was used to project Jackson's lifelike image and capture his iconic dance moves, including his legendary moonwalk (Gallo, 2014).

The hologram's lifelike movements and interactions with the live dancers left the audience in awe, evoking powerful emotions and a sense of connection with the iconic artist. The success of Michael Jackson's hologram at these occasions demonstrated the potential of hologram technology in live events, allowing audiences to relive the magic of an iconic artist and witness the power of advanced visual effects in the entertainment industry (Gallo, 2014).



Figure 2.5c - Michael Jackson's hologram at Cirque Du Soleil's 2013 show (Source: MJ Hyuga Viral YouTube video)



Figure 2.5d - Michael Jackson's hologram at the Billboard Music Awards 2014 (Source: Kevin Winter)

c. Disney's Haunted Mansion

Disney's Haunted Mansion attraction provides an iconic example in the use of hologram effects in visual storytelling to create an immersive experience for visitors. First introduced at Disneyland in 1969 and subsequently featured in various Disney theme parks, it remains the world's most recognized usage "Pepper's Ghost" effect, where holographic illusions create the appearance of ghost-like figures dancing and interacting with the physical environment [Figure 2.5c] (Reynoso, 2021). The effect is achieved by reflecting animated sequences the real story characters off an angled sheet of glass, constructing a convincing, eerie look of creatures moving

within a three-dimensional ballroom scene [Figure 2.5d] (Fitzpatrick, 2020). Being one of the earliest large-scale examples of holographic effects being used in entertainment, The Haunted Mansion has continued to captivate audiences worldwide for decades, verifying the technology's ability to emotionally engage spectators.



Figure 2.5e - Ghostly Figures in Disney's Haunted Mansion (Source: Disney)



Figure 2.5f - Holographic ballroom dancers in Disney's Haunted Mansion (Source: <https://whatculture.com/>)

d. Maisie Wilen's Holographic Collection at New York Fashion Week 2022

During New York Fashion Week 2022, designer Maisie Schloss presented her newest avant-garde collection for her fashion brand Maisie Wilen using holographic models [Figure 2.5e] (Bateman, 2022). As Schloss mentions in an interview with Bazaar, she intended the show to be “pushing visuals that make somebody question their reality” (Bateman, 2022). Using 360-degree footage simultaneously captured by more than 100 cameras at 16K solution, the 7ft digital avatars steadily rotate on the virtual stage, enabling the audience to view the garments from all angles (Campos, 2022). This creative experiment suggests a new structure of fashion

presentation that eliminates the need for human models, while also illustrating how technology is painting the picture for different sectors in the digital era (Bateman, 2022).



Figure 2.5g - Holographic models at New York Fashion Week 2022 (Source: AV Magazine)

e. Circus Roncalli's Animal Holograms

Over the past decade, the circus industry has been facing increasingly harsh restrictions on the use of animals for entertainment purposes (Melnick, 2019). In response, Circus Roncalli, from Germany, made a groundbreaking move by phasing out live animal performances and adopting holographic technology to bring the circus to life. Since 2018, Circus Roncalli's shows have stopped featuring real animals, and have instead been projecting holographic images of elephants, horses, and even fantastical creatures within the arena [Figures 2.5f & 2.5g] (Katz, 2019). To achieve this, it utilizes 11 strategically-placed projectors and a cylindrical screen that allows 360 degree-visibility (Melnick, 2019).

As the circus industry's reputation declines throughout recent years, Circus Roncalli's use of holograms has received international acclaim, prompting similar businesses to explore ethical and sustainable alternatives to conventional animal performances (Katz, 2019). The approach not only resolves an acute problem, it also generates novel experiences that were unthinkable before

incorporating digital technologies, showcasing how modern technologies could bring new wonders into traditional industries.



Figure 2.5h - Circus Roncalli's 360-degree animal projections (Source: Edgar Schoepal)

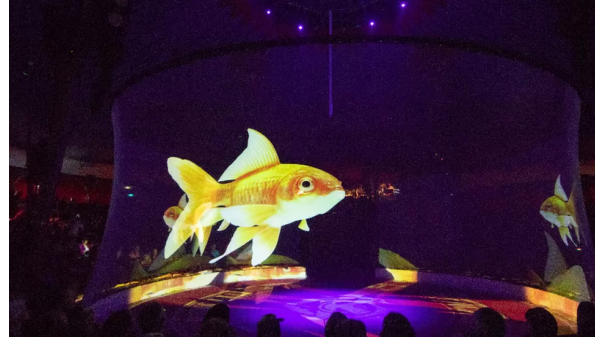


Figure 2.5i - Circus Roncalli's 360-degree animal projections (Source: Circus Roncalli)

In the examined case studies, there is an overall lack of interactivity in the current uses of hologram illusions within live entertainment settings. With many instances involving the projection of pre-rendered image sequences, current applications appear to lean toward passive consumption rather than offering dynamic and interactive engagements. In addition, since they heavily rely on two-dimensional projection surfaces, these viewing experiences often impose constraints on the audience, necessitating specific viewing angles to achieve optimal effects. This is to be explained in further detail in section 4.1: Technical Restrictions.

3. APPLICATIONS

3.1 Design Process

Designing a hologram to be used in live entertainment events involves a series of crucial steps that combine artistic creativity and technical expertise. Gathered through related interviews with industry professionals, case studies, and industry reports, a typical design and execution process is outlined as follows:

a. **Conceptualization and Ideation:**

The process begins with the conceptualization of the hologram's purpose and theme within the context of the specific live entertainment event. Artists, producers, and creative teams collaborate to brainstorm ideas, defining the key visual elements, storylines, and the overarching vision for the holographic performance, as it is vital to maintain design consistency across different teams (Webster, 2019). As noted by Adam Mackasek, a senior producer in live events, broadcast, and esports, the creative journey for designing a live event hologram often starts by mapping out the desired emotional experience for the audience throughout the performance, and all other elements are constructed with this user-centric approach (Webster, 2019).

b. **Content Creation:**

After determining the visual theme, artists and animators employ specialized modeling and rendering software to create 3D models and animations for the intended hologram projection. The approaches to the production process vary depending on the content and desired realism of the hologram. For existing real-life objects or figures, photogrammetry methods could be used to capture data and translate them into authentic 3D models (Mitchell, 2022). Conversely, cutting-edge digital technologies, like Artificial

Intelligence, enable the production of fictional appearances (The Week, 2015). For example, Tupac's hologram at Coachella 2012 utilized computer graphics and audio simulators to generate fresh movements and dialogues for the late performer through leveraging past performance footage as references (The Week, 2015).

c. Technology Selection

Technical decisions in live event hologram illusions are shaped by various factors, including budget constraints, venue size, lighting conditions, and desired visual outcomes (Webster, 2019). Among a range of techniques behind live event hologram illusions, the two most common options today are the Pepper's Ghost illusion and rendered image projection (Marinkovic, 2021). The Pepper's Ghost illusion, as discussed earlier, involves reflecting the image of an object or person onto a reflective surface at specific angles to achieve the desired visual effect. On the other hand, the popularity of rendered image projection is on the rise, utilizing ultra-high-resolution projectors to display images or animation sequences of performers on translucent screens (Marinkovic, 2021).

Leading-edge products, such as Holotronica's HoloGauze and Kaleida's 3D Holonet are making this approach increasingly feasible and appealing (Webster, 2019). In addition to the projection method, meticulous coordination of lighting is also required for creating the ideal conditions for the hologram to appear vividly and realistically within the performance environment (Reynoso, 2021).

To illustrate and validate the design process of a hologram illusion, a scaled physical model was produced for this project. See details of the model in the Appendix.

d. Integration with Live Performance:

Hologram projections are often designed to seamlessly integrate into the live performance content, creating a captivating experience where it appears to respond to events in real-time, blurring the boundaries between the physical and virtual worlds. Achieving this illusion realistically often involves careful choreography of interactions between holographic and live performers, meticulous synchronization of music and visual effects, and precise timing of holographic appearances (Webster, 2019). The scale, complexity, and desired level of interactivity of the hologram determine the timeline of the design process, where an average of several months is required for testing the hologram under various conditions and verifying its visibility from different angles (Ngak, 2012). If needed, adjustments may be made by revisiting earlier stages of the design process.

3.2 Contrast With Other Virtual Technologies

This section will examine the distinctiveness of hologram technology within the realm of live entertainment, setting it apart from other digital technologies currently employed in the field. Specifically, it will focus on comparing hologram technology with Virtual Reality (VR) and Augmented Reality (AR), which are the two most common technologies being implemented in the live entertainment landscape.

In order to understand the roles that VR and AR play within the industry, it is imperative to first establish clear definitions for both technologies. Virtual Reality (VR) refers to a computer-generated, immersive, and interactive experience that transports users to a simulated,

three-dimensional environment (Rebbani et. al., 2021). Users typically wear a headset or goggles that provide visual and sometimes auditory information, completely immersing them in a digitally created world. Through head tracking and controllers, users can interact with and navigate within this virtual environment (Rebbani et. al., 2021). Augmented Reality (AR) overlays computer-generated content, such as images, videos, or information, onto the user's real-world environment (Rebbani et. al., 2021). It enhances the user's perception of the physical world by adding virtual elements that appear to coexist in real-time with the surroundings, using devices like smartphones, smart glasses, or headsets.

There are a few key qualities that differentiate hologram technology from the two technologies. First, holograms are capable of creating a visual presence in the physical environment without the need for additional devices like headsets or goggles. As the desired effects are directly visible in the physical event space, holograms offer a distinct advantage in contributing to the *collective effervescence* that defines live events, allowing for a deeper sense of togetherness to formulate among the audience (Berkers and Michael, 2017). The design of digital technologies like VR and AR can be isolating by design as it immerses users into a digitally simulated world, isolating them from their physical surroundings and cutting off direct social interactions with others in the real world (Pringle, 2017). This goal of inviting the user into a virtual space can lead to a sense of detachment from the external environment and social isolation (Pringle, 2017). In contrast, holograms become an intrinsic part of the viewer's *actual reality*, delivering a higher emotional impact (Ng, 2021). Another benefit is its versatility in application, as they can be projected onto various surfaces and stages, adapting to different performance spaces, sizes, and configurations, making them well-suited for a wide range of live entertainment scenarios.

In recent years, entertainment technological developments have witnessed a growing emphasis on optimizing content for personalized consumption. Innovations like Apple Vision Pro, Meta Quest headsets, and Sony's PSVR each strive to deliver a world of digital and physical elements that the user could explore in their own pace and preferences (Krewell, 2023). Although these products aim to increase immersiveness by mimicking the digital world and eliminating the screen through direct projection into the user's eyes, they primarily cater to personalized experiences over interpersonal interactions (Gans & Nagaraj, 2023). This emphasis is contrary to the fundamental essence of live entertainment events, which revolves around creating a shared sense of community and collective experience (Berkers & Michael, 2017). In contrast, hologram technology excels in preserving this core value, aligning with the inherent social and emotional aspects of live entertainment. Rather than isolating individuals in their own digital worlds, holographic elements could interact with real-world performers and props, bridging the gap between the virtual and physical realms while nurturing the spirit of collective engagement in live event settings (Ng, 2021).

These advantages of holograms in live entertainment settings are expected to further strengthen with the integration of interactive elements, where audience participation will play a pivotal role in shaping the event's collective narrative (Cameron, 2006). The upcoming sections will analyze the technicalities and significance of incorporating interactivity in hologram illusions,

3.3 Incorporation Within Digital Media

In contemporary live events, the successful integration of hologram illusions with other digital media, such as lighting, sound effects, and various technologies, remains essential due to

the technical intricacies involved. While hologram technology is rapidly evolving and revolutionizing the way content is presented and experienced, it is rarely used in isolation. Instead, holograms work in synergy with other related technologies to achieve optimal results and significance, while compensating for the technology's existing shortcomings.

The collaboration with lighting and sound effects enhances the realism and impact of holographic projections in live performances, elevating the overall visual and auditory experience. Lighting plays a pivotal role in creating a harmonious blend between holographic projections and the physical stage environment (Erzberger, 2019). Since most hologram illusions today are still casting two-dimensional images to create the illusions of three-dimensional objects, exact lighting conditions are required for the projection to reach satisfactory levels of visibility and realism (Reynoso, 2021). In addition to lighting, synchronized sound effects are crucial in immersing the audience in the overall performance. An impressive example of this was witnessed during the Opening Ceremony of the League of Legends World Championships in 2019, where dynamic holographic projections were artfully choreographed to match the performed songs, electrifying the crowd [Figure 3.3a] (Erzberger, 2019). The precise combination of visual and audio effects successfully heightened the emotional impact, reaching the designers' goal to build excitement to a level where the audience was "foaming at the mouth, ready to watch these games" (Webster, 2019).

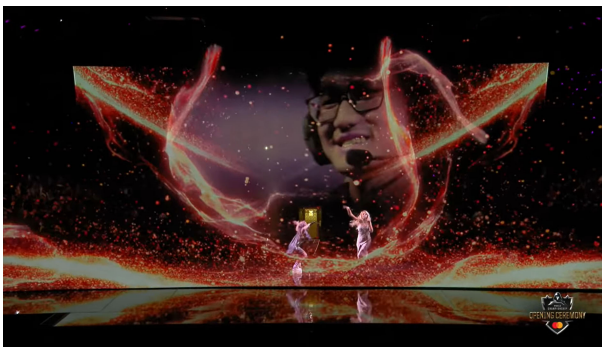


Figure 3.3a - Holographic projections at the League of Legends World Championships 2019 (Source: Live Design)

Another rising trend is the combination between hologram technology and Artificial Intelligence (AI) to offer responsive and dynamic content. AI-powered holograms can adapt their behavior based on user interactions, tailoring the experience to each individual's preferences and actions. This symbiotic relationship creates personalized and engaging digital encounters.

Looking Glass Factory, an American hologram company, recently launched their innovative product Liteform, an immersive experience featuring conversational holograms powered by OpenAI's Artificial Intelligence chatbot, ChatGPT [Figure 3.3b] (Schneider, 2023). Liteform functions as a 3D virtual assistant, projecting an animated character capable of processing users' verbal prompts and responding with corresponding "body" movements (Schneider, 2023). In a personal interview with Shawn Frayne, the co-founder and CEO of Looking Glass Factory, he emphasizes the profound influence of Artificial Intelligence on various sectors, especially in revolutionizing interactivity in the entertainment technologies (Frayne, 2023). The integration of AI breathes new life into holographic applications, which have been limited compared to other digital technologies, and promises to streamline the process of future user-generated content creation (Frayne, 2023).



Figure 3.3b - Liteforms virtual assistant (Source: Looking Glass Factory)

By augmenting its strengths and compensating for any limitations, these integrated technologies support holograms in realizing more captivating entertainment possibilities. The effective coordination of various digital components ensures that the hologram illusions deliver the desired impact, taking into account the specific conditions of the environment as well as the needs of the performance.

4. POTENTIAL CHALLENGES & LIMITATIONS

4.1 Technical Restrictions

Incorporating hologram technology has opened up a new realm of possibilities in live entertainment settings. However, alongside its advancements, there are technical restrictions that present unique challenges. This section explores the practical limitations and considerations involved in applying hologram technology, accentuating the necessary balance between artistic creativity and technical feasibility. Understanding these constraints is important for harnessing the full potential of holograms in live events and refining the experiences they could offer.

Hologram effects heavily rely on precise lighting conditions for optimal performance, with the sharpest images emerging in relatively dark environments (Kirk, 2020). However, achieving sufficient brightness can be challenging, particularly in well-lit settings or large-scale outdoor installations. If the lighting conditions are not optimized, it also reveals another key weakness of holograms: as hologram illusions are essential light bouncing off of reflective surfaces, the results they produce are always translucent to a certain extent [Figure 4.1a] (Rowell, 2019). As a result, holograms may provide captivating effects to live audiences, but their effectiveness diminishes when captured by cameras or live-streamed, with some viewers commenting that the experience of seeing hologram illusions at live shows “feels too much like watching a movie” (Matthews & Nairn, 2023). Not only does this technical flaw compromise the realism and clarity of holographic visuals, it also lowers its accessibility for visually impaired or challenged individuals compared to technologies offering more stable representations.



Figure 4.1a - Translucent holographic projections of human figures (Source: VR Scout)

Aside from projection brightness, holographic displays also typically have a recommended viewing distance and angle to maintain the desired visual experience (Rosenthal, 2021). As mentioned previously, most hologram illusions in live events today rely on either the Pepper's Ghost technique or rendered-image projection, both of which are using 2D projections to simulate 3D effects (Marinkovic, 2021). When viewers are too close, too far or deviating from the optimal angle, it may result in a diminished visual quality or even the complete loss of the holographic illusion (Rosenthal, 2021). This restriction can limit the flexibility in positioning the holographic display in certain environments.

Moreover, the successful incorporation of hologram technology in live entertainment is heavily dependent upon a specialized set of personnel with the requisite expertise and knowledge. The design, creation, and execution of hologram illusions requires a multidisciplinary team of professionals, including visual artists, animators, lighting designers, sound engineers, and technicians (Webster, 2019). Professionals need to understand not only the intricacies of holographic projection techniques but also lighting, visual effects, stage design, and even computer graphics (League of Legends, 2020). This demands a high level of technical skill and practical experience, along with a substantial time investment, which might not be readily

available among all event personnel. As hologram technology continues to evolve, the demand for skilled professionals capable of harnessing its full potential may present a challenge.

Its implementation cost stands as another significant constraint on the widespread adoption of holograms. Particularly for advanced and large-scale setups, the expenses can be substantial. For example, designing a setup to bring a deceased singer back on stage, requiring intricate digital sequences, high-resolution projectors, specialized transparent screens, and other technical components, can cost between US \$100,000 - \$400,000 (Ngak, 2012). The costs can soar even higher if interactive elements, responding to audience input, are desired. In comparison, while the use of Augmented Reality in live entertainment also varies based on factors such as scale and content creation needs, the technology has benefited from increased knowledge and flexibility over the years of its wide usage, resulting in a more cost-effective average of around US \$25,000 - \$35,000 for a typical application (Lavrentyeva, 2022). This cost difference could present a realistic barrier for many content creators seeking to incorporate hologram technology into their events.

4.2 Visual Accessibility

Building upon the limitations discussed earlier, hologram technology faces significant challenges in terms of visual accessibility, especially for individuals with visual challenges. Hologram illusions in live performances heavily rely on precise lighting conditions and specific viewing angles to achieve their three-dimensional illusions effectively (Kirk, 2020). Moreover, holograms may not translate well in recorded media, such as television broadcasts or livestreams, leading to a limited or different experience for individuals with visual challenges watching from home (Matthews & Nairn, 2023). In addition, the transparency that is inherent in hologram

illusions today might lack sufficient contrast for those with low vision, impeding their ability to discern the content clearly. Consequently, As a result, individuals with low vision or blindness may struggle to fully experience and appreciate holographic projections, as they predominantly rely on visual elements (Barabas & Bove, 2013).

As hologram technology continues to evolve and gain prominence in live entertainment, it is crucial for designers, producers, and event organizers to consider the needs of individuals with visual impairments. In addition to improving its visual representation, exploring solutions that engage other senses can enhance the overall experience, making it enjoyable for all audiences. By incorporating inclusive design practices, hologram technology can overcome these challenges and become more accessible and accommodating for a diverse range of spectators.

4.3 Psychological Impacts

As holograms introduce a new dimension of visual spectacle to the realm of entertainment, their use can potentially have significant psychological impact on audiences. As it is capable of casting hyper-realistic effects, it challenges viewers' perception of reality, blurring the line between what is real and what is merely visible, leaving viewers to question the authenticity of their experiences (Barcellos & Junior, 2015). With individuals struggling to decipher what is genuinely present and what is an illusion, it could shape new dimensions of human interactions and connections with technology, specifically fictional entities that appear to be real. A case of merging reality and dramatic illusion was seen in 2018, when a 38 year-old Japanese man Akihiko Kondo officially married Hatsune Miku, the holographic idol examined in an earlier case study [Figure 4.3a] (Sukheja, 2022). In a 2022 interview, Akihiko revealed that even four years into the marriage, his feelings for Miku have not diminished, and he considers her role as his wife to be very much real (Sukheja, 2022). Although it stands as an extreme

example, this incident showcases the potential of holograms to evoke strong motional responses that may interfere with real-life behaviours. Evidently, the psychological impact of hologram illusions could extend beyond the immediate performance setting, requiring more careful monitoring in designing virtual content that would influence viewers' perception of reality.

Furthermore, the integration of lifelike holograms with real-world objects can evoke the *uncanny valley* effect, wherein subtle inconsistencies between the real and virtual elements trigger discomfort or unease in the audience (Shoydin & Pazoev, 2022). This phenomenon becomes particularly critical when projecting real-life humans, where if the hologram reaches a certain degree of likeness with human figures, the projection “emotionally suddenly begins to be perceived by a person as a danger, as a being of another, incomprehensible and even afterlife” [Figure 4.3b] (Shoydin & Pazoev, 2022). This perception could significantly impact the overall enjoyment of the performance, and thus must be carefully avoided in all hologram technology applications. The portrayal of human characters in holographic forms also brings out ethical concerns, which will be explored further in the following sub-section.

As the technology continues to advance, it becomes essential to consider the psychological impact of holograms in live events to strike a balance between their captivating potential and their responsibilities for the effects they cast on the viewers.

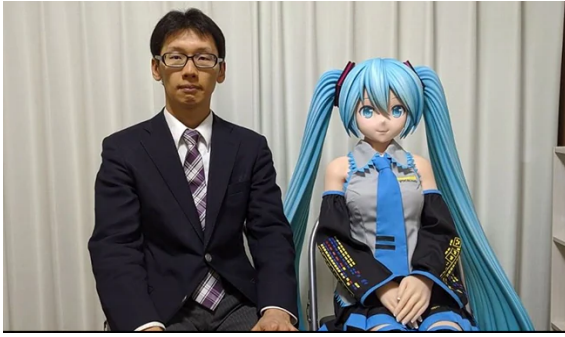


Figure 4.3a - Akihiko Kondo with Hatsune Miku
(Source: Akihiko Kondo's Instagram)

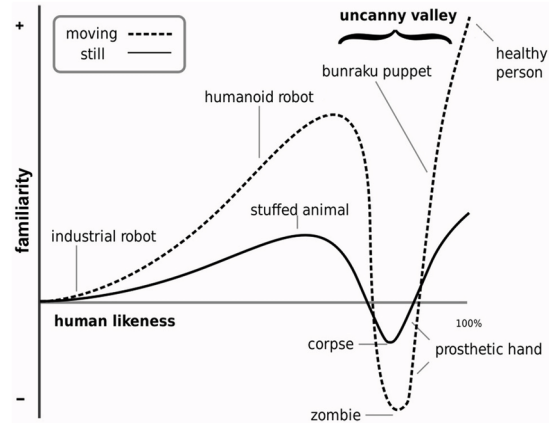


Figure 4.3b - Illustration of the Uncanny Valley Theory
(Source: Lingdan Wu)

4.4 Ethical Concerns

Holographic projections of human figures, particularly those of deceased individuals, could cause profound ethical and moral concerns. Ng states in his article that with its ability to realistically simulate a living version of a deceased individual, hologram technology offers an interesting way of reimagining the relationship between the alive and dead (Ng, 2021). However, using technology to “resurrect” late figures on stage or in other public settings raises questions about consent and privacy, potentially leading to issues of misrepresentation or defamation through exploiting their likeness and identity (Marinkovic, 2021).

Since deceased individuals cannot provide consent or voice their opinions on how they wish to be represented, the responsibility lies in the hands of others to decide on their virtual portrayal, and this decision-making process becomes particularly complex when the hologram is utilized for profit or commercial purposes (Marinkovic, 2021). Taking this one step further, if public figures can be brought back from the dead without his or her permission, businesses may

be tempted to “own the artist as an eternal possession in their hands” (Marinkovic, 2021).

Regarding this matter, the term “ghost slavery” has been coined by critics, describing the act of exploiting the legacy and memory of the deceased for financial gain. (Matthews & Nairn, 2023).

The integration of Artificial Intelligence further complicates the regulation of ethical issues surrounding hologram usage. As AI-powered projections become more sophisticated, they could potentially simulate the behaviors and personalities of deceased individuals with greater accuracy, creating fictitious but highly convincing holographic personas (Buckley, 2021). For instance, the "An Evening with Whitney Houston" 2020 tour employed AI and Computer Generated Imagery to program the movements of a body double with similar physical features to Houston, delivering a captivating performance that allowed fans to witness the late star singing on stage [Figure 4.4] (Buckley, 2021). Such advancements make it increasingly difficult to distinguish between consented representations and potentially unauthorized or exploitative use of AI-generated digital content, intensifying the need for robust ethical frameworks and clear guidelines to navigate the evolving landscape of hologram technology.



Figure 4.4a - Whitney Houston’s hologram in *An Evening with Whitney* concert (Source: Erik Kabik)

5. PRELIMINARY SUPPOSITIONS & IMPLICATIONS

5.1 Dissolving The Screen

Hologram technology's ability to "dissolve the screen", transcending the confines of traditional displays and projecting content into the physical space, distinguishes it as a powerful tool for future entertainment. Without physical (and clearly visible) devices that create a clear boundary between the audience and the content, holograms seamlessly blend into the real-world environment, allowing heightened levels of immersiveness and interactivity. Thus, this act of breaking down the "screen" is essentially redefining the relationship between the spectators and the content (Ng, 2021). Instead of passively accepting the event content, audiences can now directly engage with entertainment in novel ways and connect on multi-layers of experience.

Ng proposes that hologram technology is guiding us in embracing the "post-screen era", where human perceptions determine how a digital creation takes shape and meaning in the physical world. She suggests that although a physical screen is removed in viewing hologram illusions, individual boundaries could still exist in spectators' minds, separating their reality with the alternate version of "truth" presented through these hyper-realistic visuals (Ng, 2021). By breaking down the tangible barriers between the virtual and real, hologram technology opens up exciting possibilities for crafting impactful live entertainment experiences that appeal to the emotions of spectators. Symbolically, it also represents the liberation of creativity in the digital age, and the transcendence of traditional visual constraints.

From an architectural design perspective, removing the screen in its usage redefines the use and purpose of physical entertainment spaces, offering a paradigm shift in spatial experiences. Enhancing the physical spaces they inhabit, hologram illusions possess the power to "change the objects, activities, and even people that populate and program different structures and environments" (Cao, 2021). Moreover, if interactivity is incorporated, it could appeal to

multiple senses, redefining human relationships with the physical space where individual experiences could differ based on how they conceptualize and interpret the digital projections (Cao, 2021).

Hologram technology's exclusion of material screens signifies that interpretations of spaces are also no longer limited to what physical elements could offer, but are open to endless possibilities through digital means. The visualizations' occupation of three-dimensional space allows for richer layers of interpretation to be formed, bringing content into the same cognitive realm as the audience. With holograms transforming the way audiences engage with entertainment, future designers must envision spaces that embrace this convergence, creating immersive environments that transcend conventional boundaries and revolutionize the future of live entertainment experiences.

5.2 Sustainability And Efficiency

Hologram technology holds the potential to reform the live entertainment industry by improving its sustainability and efficiency. One of the most significant advantages lies in its capacity to reduce the need for physical props, sets, and large-scale constructions typically required in traditional entertainment productions, leading to a more sustainable approach to visual storytelling. Virtual projections can substitute materials that are difficult or cost-prohibitive to recycle, which leads to a considerable reduction in material consumption and waste generation, minimizing the industry's environmental footprint (Livingston, 2021). Moreover, the ability to create holographic visuals that are recorded and reused in different shows diminishes the need for frequent rehearsals and repetitive setup processes, and becomes less restricted by geographic limitations (less travelling of physical components), (Ngak, 2012).

The streamlining of production significantly reduces energy consumption, travel-related emissions, and overall operational costs, while offering a novel approach to engage global audiences and increasing viewing accessibility.

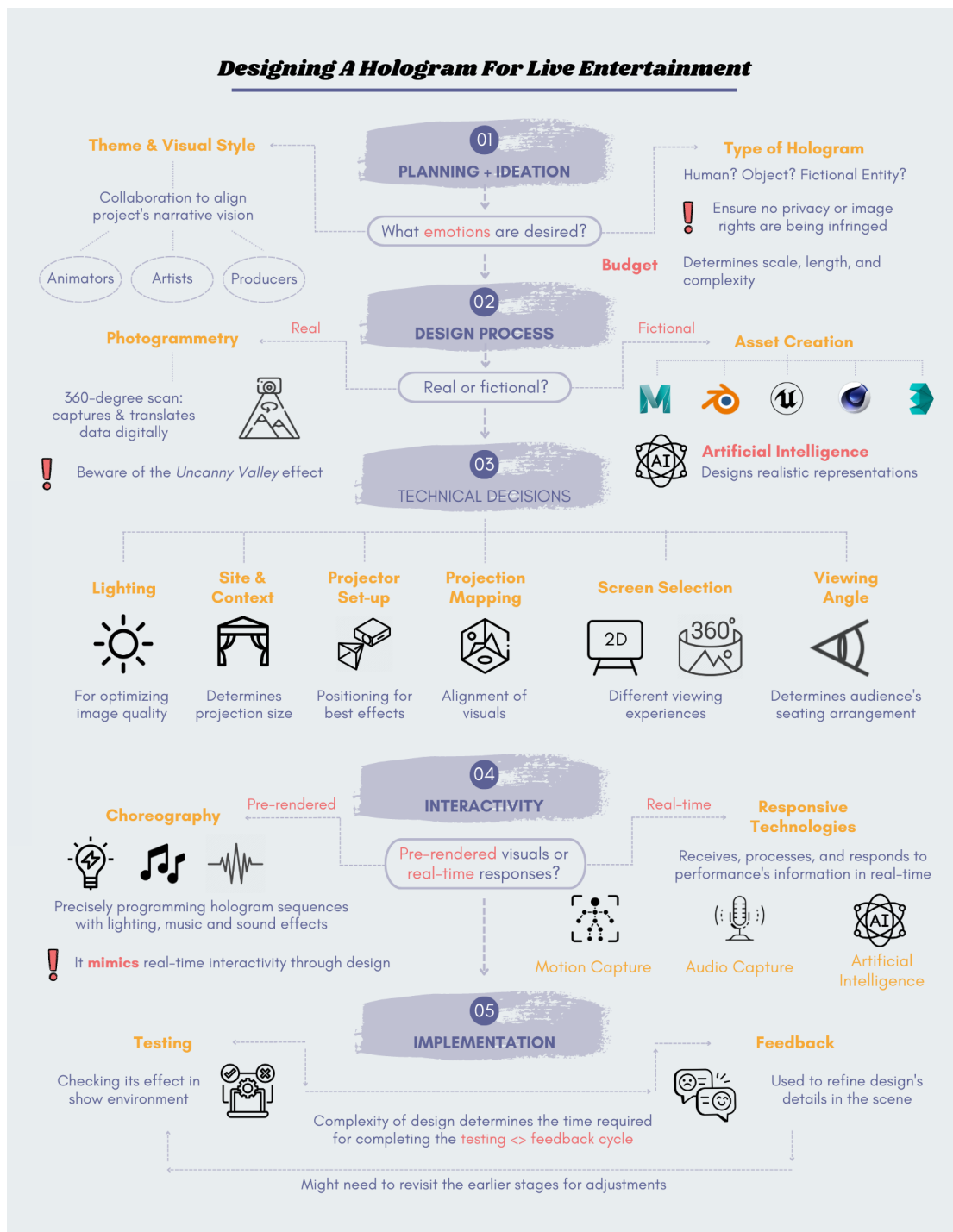
Virtual design processes is another aspect in which hologram technology can enhance efficiency. Utilizing entirely digital platforms, teams of artists, designers, and producers can collaborate seamlessly regardless of their physical locations (Dawood, 2015). By leveraging virtual tools and real-time communication, creators can efficiently iterate on designs without the need for physical prototyping, allowing shorter processes for making adjustments and improvements (Dawood, 2015). The interdisciplinary synergy could lead to innovative designs that explore the boundaries of creativity and technical feasibility. In this context, hologram technology opens doors for cross-disciplinary innovation and the integration of sustainable practices into the very core of the entertainment design process.

By redefining traditional production practices, minimizing resource consumption, and promoting virtual interactions, holograms pave the way for a greener future in entertainment. Embracing this technology not only enhances the audience experience but also aligns the industry with eco-conscious values, advocating for a more environmentally friendly and economically viable live entertainment sector.

5.3 Replicable Model For Application

The implementation processes of hologram technology have remained ambiguous and unexplored, with there being an apparent missing link between being aware of the performance possibilities and successfully incorporating this technology into live event design. Through analyzing existing industry practices and academic papers, this project aims to bridge this gap

and lower the barriers for creatively utilizing holograms for facilitating more captivating and meaningful live themed entertainment. This section proposes a practical procedure in the form of infographics for how hologram technology can become more appealing and straightforward in future applications.



5.4 Future Projections

The future of hologram technology in live entertainment holds great promise, offering creators an unparalleled platform to unleash their imagination and explore boundless creative possibilities. As holograms challenge the audience's preconceptions of what is possible, they transcend temporal, spatial, and physical restraints, opening new avenues for artistic expression. However, despite its immense potential, hologram technology remains relatively niche compared to other virtual technologies, where public awareness of its capabilities is somewhat limited. While technical restrictions present certain additional barriers for widespread usage, holograms have the potential to become a transformative force in the entertainment industry in the coming decades.

One significant trend on the horizon is the integration of holograms with Artificial Intelligence (AI), giving rise to more interactive and responsive visual effects. Precise choreography and the synchronization of holographic effects with live performance elements are sometimes employed to simulate real-time interactivity, but with the incorporation of AI, the technology could genuinely become responsive in real time (Erzberger, 2019). The introduction of Liteforms by the Looking Glass Company exemplifies how AI-powered holograms can dynamically adapt to audience reactions, offering personalized experiences that deeply resonate with each viewer (Schneider, 2023). As modern audiences increasingly seek immersive narratives and meaningful participation, AI integration vitalizes holograms in novel ways, allowing viewers to actively shape the unfolding entertainment experiences through their feedback (Frayne, 2023). While the scale of applications in live performances holds immense potential, Frayne acknowledges that achieving satisfactory visual results at performance scale might incur substantial costs (Frayne, 2023). Nevertheless, he holds optimism surrounding AI's

ability to elevate hologram technology to new heights, with the technology projected to become more prevalent than VR and AR in the near future (Frayne, 2023).

Related to the increasingly wide applications of Artificial Intelligence, another emerging trend in the entertainment realm is the rise of virtual idols and digital avatars. A prominent example is Lil Miquela, also known as Miquela Sousa or simply Miquela, who is a virtual influencer and digital character who first gained prominence on Instagram in 2016 [Figure 5.4a] (Petrarca, 2018). With a highly realistic appearance, she is a computer-generated avatar who has accumulated a large and dedicated fanbase for her fashion-forward style, activism, and engaging social media presence (Tiffany, 2019). Despite her virtual nature, Miquela has collaborated with various brands, celebrities, and other digital personalities [Figure 5.4b]. In 2019, her creators, American software startup Brud, has also received \$125 million investment in a funding round as a result her successful debut (Tiffany, 2019). This evident trend of embracing virtual and digitally created personas could foreshadow a similar trajectory for hologram technology, further merging digital elements with real world contexts. As hologram technology advances, audiences can expect to witness awe-inspiring live entertainment events featuring these digital celebrities, captivating fans worldwide.



Figure 5.4a - Lil Miquela (Source: Lil Miquela's Instagram)



Figure 5.4b - Calvin Klein ad with Bella Hadid & Lil Miquela (Source: Calvin Klein)

Referencing back to hologram technology's ability to "dissolve the screen" and emphasize the intangible qualities of physical spaces, it suggests a trend that future entertainment spatial designs will prioritize producing adaptable and interactive spaces that accommodate and dynamic storytelling, fostering a harmonious coexistence between the physical and virtual realms. The Madison Square Garden (MSG) Sphere in Las Vegas serves as an outstanding example of how digital media is being applied on a large public scale. Standing at 366 feet tall and 516 feet wide, it is the world's largest spherical structure with the highest-resolution wraparound LED screen that projects stunning, realistic visual effects [Figure 5.4c] (Griggs, 2023). With a seating capacity of around 18,000 people, the multi-purpose structure is designed to host live music, immersive theatre, and sporting events (Griggs, 2023). Within its interior, it features a remarkable 160,000-square-foot high-resolution screen, complemented by an immersive 170,000-speaker sound system, and interactive stage technologies that collectively redefine the boundaries of sensory experiences within an entertainment environment [Figure

5.4d] (Haas, 2023). The MSG Sphere demonstrates a clear growing interest in creating immersive and impactful narratives for large audiences, where advancements in digital means are immensely enhancing the live entertainment experience (Crook, 2023). It represents a glimpse into the future of entertainment, where digital media's integration on a grand scale will continue to redefine the ways audiences experience and interact with live entertainment on a global level.



Figure 5.4c - The MSG Sphere on the 4th of July, 2023 (Source: L. E. Baskow/Las Vegas Review Journal)

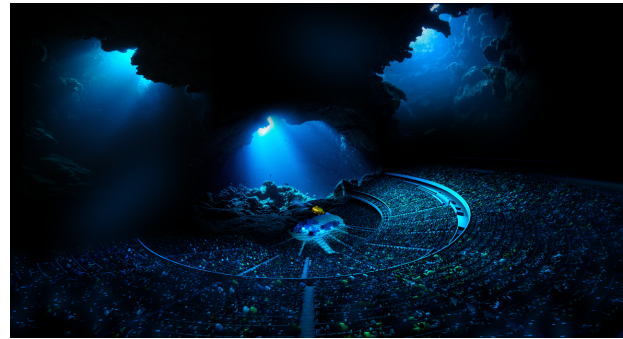


Figure 5.4d - Interior render of the MSG Sphere (Source: Sphere Entertainment)

While hologram technology already offers distinctive experiences, there remains untapped potential for advancements that can open new opportunities for its capabilities. By presenting ideas in three-dimensional form, holograms can exceed the limitations of traditional two-dimensional mediums, transforming physical spaces in novel ways. Thus, the next focus of technological development is likely to revolve around spatial interaction, empowering creators to design visuals that dynamically adapt to the viewer's perspective and movements. This interactive dimension will unlock fresh ways to engage audiences, encouraging active participation and fostering a sense of exploration and discovery. The evolution of hologram technology is set to reshape the creative landscape, offering unparalleled levels of engagement and immersion. Furthermore, continuous efforts to address its current technical restrictions, such

as expanding viewing angles, simplifying content creation processes, and reducing costs are necessary in making the technology more accessible and practical for larger-scale applications.

Overall, the implementation of hologram technology in entertainment has been marked by sporadic experimentations rather than systematic explorations. While holograms have made occasional appearances in live events, concerts, and exhibitions, their full potential and capabilities have not been systematically harnessed. As the technology continues to evolve, there is an exciting opportunity for the industry to conduct more comprehensive research and experimentation, unlocking its possibilities for creating unforgettable and interactive live entertainment experiences.

6. SUMMARY AND CONCLUSIONS

In conclusion, interactive hologram technology represents a groundbreaking solution with the potential to reconstruct the live entertainment industry. Its ability to create personalized and interactive content enables performers to engage with their fans on a deeper emotional level, fostering a sense of community and collective effervescence. As hologram technology continues to evolve, its integration with other cutting-edge digital technologies, such as Artificial Intelligence, holds tremendous promise for the future of live entertainment. The growing popularity of digital media across different sectors indicate a trajectory where virtual technologies would be leading the way for future content creation, creating worlds where imagination and reality intertwine in mesmerizing ways.

Moreover, the potential sustainability benefits of hologram technology, including reduced material consumption and minimized travel requirements, align with the industry's increasing focus on eco-conscious practices. In addition, the democratization of holographic experiences through virtual and augmented reality platforms opens up new possibilities for global audience engagement, making live events more accessible to a broader demographic.

In conclusion, interactive hologram technology is on the brink of reshaping the live entertainment landscape. With its ability to create awe-inspiring performances, foster meaningful connections, and embrace sustainable practices, holograms are poised to become a driving force in the future of entertainment. As the industry continues to embrace innovation and technological advancements, the future projections of hologram technology hold boundless opportunities for captivating and immersive live experiences that will redefine the essence of entertainment as we know it.

APPENDIX

A physical model was produced for this project to simulate how hologram illusions could take form within a live entertainment context [Figure A1-A2]. The model employs a simple projection technique: a pre-rendered animated sequence is played on a phone positioned facedown on a clear acrylic surface. The sequence is reflected onto an angled piece of acrylic beneath it, becoming visible to the viewer and creating the illusion of an image situated behind the pane [Figure A3].

The design was initially crafted using Blender 3D software, helping to define the necessary scale and dimensions for each component. Following this, the components were laser-cut and assembled using acrylic sheets.

Various thicknesses of the angled projection surface were tested to achieve an optimal projection quality. The initial iteration, using 3mm clear acrylic, resulted in an image that was out of focus [Figure A4]. Transitioning to a slimmer 1mm piece, however, resulted in a substantial enhancement in image quality [Figure A5]. The experimentation provided valuable insights into the various stages and aspects to consider when designing hologram effects, requiring attention to details such as how different surface thicknesses influence the clarity and visual fidelity of the projected image. In a broader sense, it offered a glimpse into how technical nuances of this nature can wield significant influence over the outcomes of holographic projections, especially when applied on a larger scale.



Figure 1 - Physical model



Figure 2 - Physical model

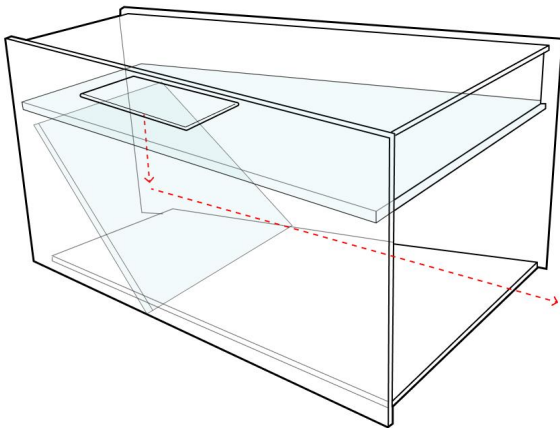


Figure 3 - Illustration of the projection path

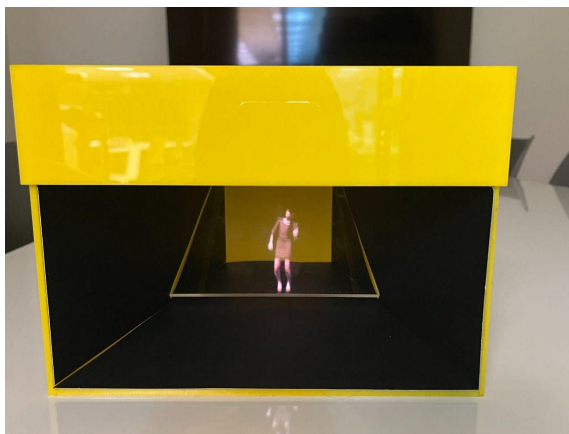


Figure 4 - Using 3mm projection surface



Figure 5 - Using 1mm projection surface

REFERENCES

- A close look at the growth of the entertainment industry over the years*. The World Financial Review. (2021).
<https://worldfinancialreview.com/a-close-look-at-the-growth-of-the-entertainment-industry-over-the-years/>
- Anderson, M. (1991). The changing scene: Plays and playhouses in the Italian Renaissance. *Theatre of the English and Italian Renaissance*, 3–20.
https://doi.org/10.1007/978-1-349-21736-6_1
- Barabas, J., & Bove, V. M. (2013). Visual perception and holographic displays. *Journal of Physics: Conference Series*, 415, 012056.
<https://doi.org/10.1088/1742-6596/415/1/012056>
- Barcellos, E. E., & Junior, G. B. (2015). The interactive holography as metaphor and innovation in optical representation in Design. *Procedia Manufacturing*, 3, 754–761.
<https://doi.org/10.1016/j.promfg.2015.07.319>
- Bateman, K. (2022). *Maisie Wilen's hologram fashion show pushed boundaries*. Harper's BAZAAR.
<https://www.harpersbazaar.com/fashion/fashion-week/a39046981/maisie-wilen-fall-2022/>
- Berkers, P. & Michael, J. (2017). Just what is it that makes today's music festivals so appealing? *Music Brings Us Together: art and music festivals*, 98-115
- Berry, Y. (2023). *Holograms: The future of performance: The babel flute*. The Babel Flute | International Flute Magazine & Community.

<https://thebelflute.com/holograms-the-future-of-performance/>

Buckley, P. (2023). *The hologram concert - how AI is helping to Keep Music alive*. Telefónica Tech.

<https://telefonicatech.com/en/blog/the-hologram-concert-how-ai-is-helping-to-keep-music-alive>

Cameron, S. (2006). Determinants of the Demand for Live Entertainments: Some Survey-based Evidence. *Economic Issues* (Stoke-on-Trent, England), 11(2), 51-64

Campos, G. (2022). *New York Fashion Week hosts “first all-holographic show.”* AV Magazine.

<https://www.avinteractive.com/news/video/new-york-fashion-week-hosts-first-holographic-show-03-03-2022/>

Cao, L. (2021). *Holography: How it could change architectural space*. ArchDaily.

<https://www.archdaily.com/963011/holography-how-it-could-change-architectural-space>

Carlton, B. (2023). *This year’s Coachella featured immersive AR Portals*. VRScout.

<https://vrscout.com/news/this-years-coachella-featured-immersive-ar-portals/>

Chow, A. R. (2022). *How flume and Unreal Engine brought Coachella into the metaverse*. Time.

<https://time.com/6168688/coachella-enters-the-metaverse/>

Costola, S. (2009). Strategies of subversion: The power of live performance within the walls of a Renaissance City. *International Journal of Arts and Technology*, 2(3), 187.

<https://doi.org/10.1504/ijart.2009.028925>

Crook, L. (2023). *World’s largest spherical structure unveiled in Las Vegas*. Dezeen.

<https://www.dezeen.com/2023/07/06/msg-sphere-las-vegas-unveiled/>

Davies, D. (2023). *Live music streaming: Developing a new performance paradigm*. IBC.

<https://www.ibc.org/features/live-music-streaming-developing-a-new-performance-paradigm/9470.article>

Dawood, S. (2017). *How holograms could change the way product designers work*. Design Week.

<https://www.designweek.co.uk/issues/7-13-december-2015/how-holograms-could-change-the-way-product-designers-work/>

De Felice, F., De Luca, C., Chiara, S. D., & Petrillo, A. (2023). Physical and digital worlds:

Implications and opportunities of the metaverse. *Procedia Computer Science*, 217,

1744–1754. <https://doi.org/10.1016/j.procs.2022.12.374>

Erzberger, T. (2019). *Riot games debuts hologram tech for League of Legends World*

Championship Final Opening Ceremony. ESPN.

https://www.espn.com/esports/story/_/id/28045340/riot-games-debuts-hologram-tech-league-legends-world-championship-final-opening-ceremony

Fitzpatrick, J. (2020). *Friday fun: Here's how the disney haunted mansion ghosts work*.

LifeSavvy RSS.

<https://www.lifesavvy.com/11887/friday-fun-heres-how-the-disney-haunted-mansion-ghosts-work/>

Frankfurt, T. (2022). *How in-person events have evolved post pandemic*. Entrepreneur.

<https://www.entrepreneur.com/leadership/how-in-person-events-have-evolved-post-pandemic/439531>

Frayne, S. (2023). Interview.

Gallo, P. (2014). *Michael Jackson hologram rocks billboard music awards: Watch & go behind the scenes*. Billboard.

<https://www.billboard.com/music/music-news/michael-jackson-hologram-billboard-music-awards-6092040/>

Gans, J., & Nagaraj, A. (2023). *What is Apple's vision pro really for?* Harvard Business Review.

<https://hbr.org/2023/06/what-is-apples-vision-pro-really-for>

Greenburg, Z. O. (2013). *Michael Jackson returns to the stage in Vegas--as a hologram*. Forbes.

<https://www.forbes.com/sites/zackomalleygreenburg/2013/05/24/michael-jacksons-hologram-rocks-las-vegas-arena/?sh=5eac98723369>

Griggs, B. (2023). *This futuristic concert venue in Las Vegas is a giant sphere with the world's biggest led Screen*. CNN.

<https://www.cnn.com/2023/07/05/travel/msg-sphere-las-vegas-venue-cec/index.html>

Haas, G. (2023). *Inside sphere: Mysteries ahead after July 4th show*. KLAS.

<https://www.8newsnow.com/news/local-news/heres-what-we-know-about-the-inside-of-sphere-in-las-vegas/>

Haleem, A., Javaid, M., Singh, R. P., Suman, R., & Rab, S. (2022). Holography and its applications for industry 4.0: An overview. *Internet of Things and Cyber-Physical Systems*, 2, 42–48.

<https://doi.org/10.1016/j.iotcps.2022.05.004>

Hall, D. (2018). *Holograms: Are they still the preserve of science fiction?*. The Guardian.

<https://www.theguardian.com/technology/2018/may/22/star-wars-holograms-3d-images-future-holocheess-princess-leia>

Jain, V. (2022). *Council post: Virtual and hybrid events are more than just a covid-era fix*.

Forbes.

<https://www.forbes.com/sites/forbesbusinesscouncil/2022/12/20/virtual-and-hybrid-events-are-more-than-just-a-covid-era-fix/?sh=22f84de365cb>

Katz, B. (2019). *A German circus uses stunning holograms instead of live animal performers*.

Smithsonian.com.

<https://www.smithsonianmag.com/smart-news/german-circus-uses-stunning-holograms-instead-live-animal-performers-180972376/>

Kirk, S. (2020). *Hologram technology and its application in arts and entertainment: Part 2*.

AMT Lab @ CMU.

<https://amt-lab.org/blog/2020/3/hologram-technology-and-application-in-the-arts>

Krewell, K. (2023). *Apple's vision pro: What it is and what it is not*. Forbes.

<https://www.forbes.com/sites/tiriasresearch/2023/07/05/apples-vision-pro-what-it-is-and-what-it-is-not/?sh=446f6a992f16>

Kurin, R. (2017). *From radio to television: The History of Electronic Communication*.

Wondrium Daily.

<https://www.wondriumdaily.com/radio-television-history-of-electronic-communication/#:~:text=In%201895%2C%20the%20Italian%20inventor,tuned%2C%20or%20syntonic%2C%20telegraphy.>

Livingston, M. (2022). *Council post: Can technology define the hour of reckoning for our planet?*. Forbes.

<https://www.forbes.com/sites/forbestechcouncil/2021/10/26/can-technology-define-the-hour-of-reckoning-for-our-planet/?sh=49bfl02924e2>

Lavrentyeva, Y. (2023). *How much does augmented reality cost? key factors & real-world examples*. ITREx.

<https://itrexgroup.com/blog/augmented-reality-cost-factors-examples/>

League of Legends. (2020). *10 months, 10 minutes | worlds 2019 opening ceremony presented by Mastercard*. YouTube. <https://www.youtube.com/watch?v=HyX6MRs506M>

Machkovech, S. (2016). *Review: Japanese hologram pop star Hatsune Miku tours north america*. Ars Technica.

<https://arstechnica.com/gaming/2016/04/waving-glow-sticks-at-hologram-anime-pop-stars-our-night-with-hatsune-miku/#:~:text=And%2C%20yes%2C%20let%20me%20repeat,a nime%20character%20the%20concertgoer%20pleased.>

MacNeal, D. (2022). *Spectral illusions: The pepper's ghost effect*. Art of Play.

<https://www.artofplay.com/blogs/stories/spectral-illusions-the-peppers-ghost-effect-and-how-it-works>

Marchand, L. (2020). *Holographic pop star Hatsune Miku to perform Montreal*

concert | *CBC News*. CBCnews.

<https://www.cbc.ca/news/canada/montreal/hatsune-miku-mtl-1.5445686>

Malleck, J. (2023). *Beyoncé and Taylor Swift are poised to knock out the record holder for highest-grossing tour of All time*. Quartz.

<https://qz.com/beyonce-taylor-swift-renaissance-eras-tour-record-1850454458>

Marinkovic, P. (2021). *Hologram artists - the future of live performance*. Medium.

<https://medium.com/predict/hologram-artists-the-future-of-live-performance-9851d2e02ael>

Matthews, J., & Nairn, A. (2023). *Holograms and AI can bring performers back from the dead – but will the fans keep buying it?*. The Conversation.

<https://theconversation.com/holograms-and-ai-can-bring-performers-back-from-the-dead-but-will-the-fans-keep-buying-it-202431#:~:text=With%20the%20exception%20of%20ABBA's,with%20the%20band%20and%20audience.>

McGowan, C. (2022). *Experiencing the Rise of Immersive Entertainment*. The Magazine of the Visual Effects Society.

<https://www.vfxvoice.com/experiencing-the-rise-of-immersive-entertainment/>

Medium. (2018). *The impending Golden Age of Interactive Entertainment*. Medium.

<https://medium.com/@makers.kowloon/on-the-eve-of-a-golden-age-of-interactive-entertainment-9975c17e3f2c>

Melnick, K. (2019). *German circus ends its use of live animals in favor of 3D holograms*.

VRScout. <https://vrscout.com/news/german-circus-3d-holographic-animals/>

Mitchell, J. (2022). *A filmmaker's guide to creating holograms*. The Beat: A Blog by PremiumBeat.

<https://www.premiumbeat.com/blog/filmmaker-guide-to-creating-holograms>

Ng, J. (2021). The post-screen through virtual reality, holograms and light projections.

<https://doi.org/10.1017/9789048552566>

Ngak, C. (2018). *Tupac Coachella Hologram: Behind the technology*. CBS News.

<https://www.cbsnews.com/news/tupac-coachella-hologram-behind-the-technology/>

Petrarca, E. (2018). *Lil Miquela's body con job*. The Cut.

<https://www.thecut.com/2018/05/lil-miquela-digital-avatar-instagram-influencer.html>

Petronio, K. (2020). *The history of Live Music Performance*. Savage Content.

<https://www.savagecontent.com/post/the-history-of-live-music-performance>

PricewaterhouseCoopers. (2023). *Global Entertainment and Media Outlook 2023–2027*. PwC.

<https://www.pwc.com/gx/en/industries/tmt/media/outlook/insights-and-perspectives.html#:~:text=Taking%20into%20account%20all%20live,predicted%20for%20overall%20consumer%20revenue>

Pringle, R. (2017). Opinion | virtual reality is still too isolating to be “the next big thing” in tech:

Opinion | CBC news. CBCnews.

<https://www.cbc.ca/news/opinion/vr-isolation-1.3980539>

Rebbani, Z., Azougagh, D., Bahatti, L., & Bouattane, O. (2021). Definitions and applications of augmented/virtual reality: A survey. *International Journal of Emerging Trends in*

- Engineering Research*, 9(3), 279–285. <https://doi.org/10.30534/ijeter/2021/21932021>
- Rehagen, T. (2022). *One of Japan's most beloved pop stars is a hologram*. Experience Magazine. <https://expmag.com/2021/05/one-of-japans-most-beloved-pop-stars-is-a-hologram/>
- Reynoso, M. (2021). *This haunted mansion illusion is hundreds of years old!*. Inside the Magic. <https://insidethemagic.net/2021/03/haunted-mansion-illusion-mr1/>
- Rosenthal, L. (2021). *Could holograms be the future of entertainment and advertising?*. Rolling Stone. <https://www.rollingstone.com/culture-council/articles/holograms-future-entertainment-advertising-1268769/>
- Rowell, D. (2019). *Dead musicians are taking the stage again in hologram form. is this the kind of encore we really want?*. The Washington Post. <https://www.washingtonpost.com/magazine/2019/10/30/dead-musicians-are-taking-stage-again-hologram-form-is-this-kind-encore-we-really-want/>
- Ryu, S., & Cho, D. (2022). The show must go on? the entertainment industry during (and after) COVID-19. *Media, Culture & Society*, 44(3), 591–600. <https://doi.org/10.1177/01634437221079561>
- Samek, M. (2021). Stories incarnate: Designing embodied, interactive storytelling experiences for live audiences. <https://doi.org/10.32920/ryerson.14654232.v1>
- Schaus, G. P., & Wenn, S. R. (2007). Onward to the Olympics: Historical perspectives on the Olympic Games. *Choice Reviews Online*, 45(01). <https://doi.org/10.5860/choice.45-0339>

- Schneider, J. (2023). *Looking Glass “liteforms” are holograms you can talk with*. PetaPixel.
<https://petapixel.com/2023/05/23/looking-glass-liteforms-are-holograms-you-can-talk-with/>
- Shirzadian, N., Redi, J. A., Rögglä, T., Panza, A., Nack, F., & Cesar, P. (2018). Immersion and togetherness: How live visualization of audience engagement can enhance music events. *Advances in Computer Entertainment Technology*, 488–507.
https://doi.org/10.1007/978-3-319-76270-8_34
- Shoydin, S. A., & Pazoev, A. L. (2022). «uncanny valley» effect in holographic image transmission. *Journal of the Belarusian State University. Physics*, (3), 4–9.
<https://doi.org/10.33581/2520-2243-2022-3-4-9>
- Sukheja, B. (2022). *Japanese man who married fictional character in 2018 now struggles to connect with her*. NDTV.com.
<https://www.ndtv.com/offbeat/japanese-man-who-married-fictional-character-in-2018-now-struggles-to-connect-with-her-2924199>
- Swarbrick, D., Seibt, B., Grinspun, N., & Vuoskoski, J. K. (2021). *Corona concerts: The effect of virtual concert characteristics on Social Connection and kama muta*. Frontiers. <https://www.frontiersin.org/articles/10.3389/fpsyg.2021.648448/full>
- The Week Staff. (2015). *Coachella’s “Astonishing” tupac shakur hologram: How they did it*. The Week.
<https://theweek.com/articles/476386/coachellas-astonishing-tupac-shakur-hologram-how-did>

- Tiffany, K. (2019). *Lil Miquela and the Virtual Influencer Hype, explained*. Vox.
<https://www.vox.com/the-goods/2019/6/3/18647626/instagram-virtual-influencers-lil-miquela-ai-startups>
- Troseth, G. L., Flores, I., & Stuckelman, Z. D. (2019). When representation becomes reality: Interactive Digital Media and symbolic development. *Advances in Child Development and Behavior*, 65–108. <https://doi.org/10.1016/bs.acdb.2018.12.001>
- United Talent Agency. (n.d.). *Post Covid Study_Vol 2 062321.PDF: Powered by box*. Box.
<https://unitedtalent.app.box.com/s/fcaha4xzcbvqtvcs3q9e03esmvhqaab1>
- Valadez, A. A., & Jeremijenko, A. (2022). Can hologram technology promote family connection and combat anxiety and depression in oil and gas employees? *The APPEA Journal*, 62(2).
<https://doi.org/10.1071/aj21068>
- Vorderer, P., Knobloch, S., & Schramm, H. (2001). Does entertainment suffer from interactivity? the impact of watching an interactive TV movie on viewers' experience of entertainment. *Media Psychology*, 3(4), 343–363. https://doi.org/10.1207/s1532785xmep0304_03
- Webster, A. (2019). *Designing League of Legends' Stunning Holographic Worlds Opening Ceremony*. The Verge.
<https://www.theverge.com/2019/11/11/20959206/league-of-legends-worlds-2019-opening-ceremony-holograms-holonet>
- Williams, B. (2023). *The Future of Online Entertainment: How Technology is changing the way we have fun*. The London Economic.

<https://www.thelondoneconomic.com/tech-auto/technology/the-future-of-online-entertainment-how-technology-is-changing-the-way-we-have-fun-349159/>

Woltmann, S. (2023). *What is Immersive Theatre? definition + examples | backstage*. Backstage.
<https://www.backstage.com/magazine/article/immersive-theatre-explained-75850/>