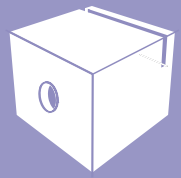
Published by:



EARLY VISUAL MEDIA LAB

CICANT

Ermo Säks is a visiting research fellow and lecturer at the Baltic Film, Media and Arts School (BFM) at Tallinn University, Estonia. His primary focus of research revolves around cinematic virtual reality (CVR), alongside interests in media, communication, emerging technologies, and the metaverse. ORCID**:** https://orcid.org/0009-0009-0706-2769

Ermo Säks
Narva rd 27, 10120 Tallinn, Estonia
ermo.saks@tlu.ee

Acknowledgements
All images are published under "fair use" for academic purposes. The author would like to thank Victor Flores and Carolina Martins.

LIGHTING IN CINEMATIC VIRTUAL REALITY

ERMO SÄKS
Visiting Research Fellow,
Centre of Excellence in Media Innovation and Digital Culture (MEDIT),
Baltic Film, Media and Arts School (BFM), Tallinn University, Estonia

INTERNATIONAL JOURNAL ON STEREO & IMMERSIVE MEDIA, Vol. 7 No. 1
pp. 120-135
DOI: 10.24140/ijsim.v7.n1.06
ijsim.ulusofona.pt

Abstract

With the emergence of inexpensive virtual reality (VR) head-mounted display (HMD) systems in recent years, VR has become commercially viable and more widely popular with some 200 million users worldwide. An important role in this take-up has been the development of cinematic virtual reality (CVR). As in any imagery, lighting design is one of the crucial elements in CVR that can greatly enhance the immersive experience in creating a desired look and feel and an engaging environment for the viewers to explore. However, there is currently very limited research on how set lighting can be and is used in CVR productions. This paper aims to fill this gap by reviewing the prevalent concepts for set lighting 360-degree videos which are companioned by examples by studying an existing CVR drama genre experience *Wiktoria 1920*. This paper investigates four set lighting strategies used in CVR: natural or ambient lighting, practical lighting, hidden lighting, and mixed lighting.

Keywords: cinematic virtual reality, 360-degree video, set lighting, illumination, head-mounted display

The Birth of Virtual Reality

The creation of the stereoscope marks the beginning of VR technology. Sir Charles Wheatstone, a scientist and inventor, proposed in 1838 that humans see the world in depth because we have two eyes that are somewhat apart. As a result, with each eye viewing from slightly different angles, the parallax difference between what our eyes see is interpreted as depth. Wheatstone invented a stereoscope, which allows a person to see two pictures drawn from separate viewpoints, one for each eye. His idea was proven right, and the mechanism that used mirrors to integrate the two viewpoints was the first mechanical way of seeing a recreated three-dimensional image (Wheatstone, 1838, 1852; Wade, 2012; Tricart, 2017; Säks, 2022).

Sir David Brewster enhanced Wheatstone's unwieldy stereoscope with mirrors in 1849 by transforming it into a portable device, with mirrors replaced with optical lenses to unify the stereoscopic views. In 1861, Oliver Wendell Holmes, Sr. invented an even simpler and less costly stereoscope than Brewster's. Holmes elected not to obtain a patent in order to encourage mass manufacture and widespread use. As a result, stereoscopes were a common type of home entertainment, with millions of stereoscopic pictures made and sold up to the 1920s, mainly in the United States, and England but also in other countries (West, 1996; Tricart, 2017; Säks, 2022). Tricart (2017) notes that in many respects, things have gone full circle: Google's Cardboard as a cheap mass-produced VR viewer is essentially similar in function and form to its analogue progenitor – Holmes's patent-free stereoscope from over 150 years ago.

Cinematic Virtual Reality

With the emergence of inexpensive VR HMD systems in recent years, VR has become commercially viable and more widely popular with some 200 million users worldwide (Katatikarn, 2023; Tong et al., 2021). A significant influence in VR adoption has been the development of CVR. The emerging consensus is that the term CVR (also *Film VR* or *Live Action VR*) can be defined as a type of experience where the viewer watches omnidirectional movies using HMD and consequently, as the viewer can freely choose the viewing direction, they can develop a feeling of being there within the scenes (Säks 2022; Dooley, 2021; Tong et al., 2021; Ross, Munt, 2018; Mateer, 2017).

The prefix *cinematic* refers to when the 360-degree video is narrative-based rather than solely for novelty, amusement or exploration and the content [story] features a beginning, middle, and an end. The distinction between VR and CVR is in how the VR environment is formed: in traditional VR, it is often generated in real-time through 3D graphics processing and audio triggers, whereas CVR uses pre-rendered visuals and sound elements exclusively. By lacking interactivity, the audience is invited to *sit and relax* and witness the story being told as the participants are immersed in a 360-degree sphere, with three degrees of freedom (3DoF) – meaning the freedom of head rotation, i.e., pitch, yaw, and roll (Säks, 2022; Dooley, 2021; Ross, Munt, 2018; Tricart, 2017; Mateer, 2017).

This new medium presents many opportunities but also challenges. According to classical film theory, narrative space is primarily generated and reconstructed through two cinematic

techniques: framing/composition and continuity editing (Bordwell et al., 1985), but in CVR, this idea only exists in terms of the viewer's peripheral vision, which "frames" their watching experience in the same manner that we receive visual information in reality (Moody, 2017). This means that CVR offers viewers immersive experiences by providing the opportunity to look in any direction desired, allowing them to explore the surroundings as if they were physically present, but because of the nature of CVR, there is no "behind" for the 360-degree camera and the placement of technical equipment – and in particular set lighting – is a challenge (Rakkolainen et al., 2018; Vosmeer & Schouten, 2017).

CVR Experience Wiktoria 1920

In this paper, the Polish CVR period film *Wiktoria 1920* (Niepodległa, n.d.), directed by Tomasz Dobosz, is studied in order to analyse and demonstrate the usage of different set lighting techniques in CVR. *Wiktoria 1920* is an adventure story created for the hundredth anniversary of the Battle of Warsaw reflecting the Polish-Bolshevik war. It begins in August 1920 and follows Janek Wgielski (viewer watching the film), Uhlan Wadysaw Broczak and Merian C. Cooper, who embark on an adventure towards Warsaw to deliver a mysterious report to the Citadel. They travel by plane, but the damaged machine must make an emergency landing. Unfortunately, the area where they land is full of Bolsheviks, but the heroes manage to escape from them. They take part in the fighting while trying to deliver the report that might affect the fate of one of the most important battles in the history of not only Poland but also the world (Niepodległa, n.d.).

The CVR experience *Wiktoria 1920* was chosen as the study material because it a) uses different lighting techniques for lighting the scenes, b) is freely accessible on the internet, c) features distinctive characteristics of a CVR film offering three degrees of freedom (3DoF), d) features the distinctive characteristic of a CVR film by telling a fixed narrative story that, due to the limited nature of the viewer's capacity to influence the path of the story, plays out to a predetermined conclusion.

The Prevalent Concepts for Lighting a 360-degree Video

As in any imagery, lighting plays a crucial role in CVR. Firstly, for viewers to see what is happening altogether and secondly, to create the desired look and feel to best engage viewers (Zhang & Weber, 2021; Felnhofer et al., 2015). Naturally, the lighting in CVR can vary based on the production and desired impact. However, typical lighting setups used in traditional cinematography might be difficult to execute without the equipment shown in the shot (Zhang & Weber, 2021; Bucher, 2017; Tricart, 2017). As a result, to illuminate the scene, creators often need to employ a creative approach, different strategies and techniques which can be divided into four categories: natural or ambient lighting, practical lighting, hidden lighting, and mixed lighting.

Natural and Ambient Lighting

Using natural or ambient light is the most simple and cost-effective way to light the scene as it requires minimal setup time since no additional equipment is needed. Natural light, such as sunlight or moonlight, or ambient light, such as street lights

Fig. 1 Still Image of Wiktoria 1920 (Tomasz Dobosz, 2020)

or fireplaces, provides the primary illumination that produces even and diffused lighting, creating a realistic atmosphere. It adds authenticity to the footage by capturing actual shadows, highlights, and reflections from objects in the environment. This method is especially widespread for daytime shooting, outdoor shooting or scenes that take place in an environment with large windows. However, natural light can be unpredictable and difficult to manage, therefore creators must be aware of the weather conditions, the time of day and the movement of the sun to avoid inconsistencies across different parts of the footage (Zhang & Weber, 2021; Tricart, 2017).

The usage of natural daylight in *Wiktoria 1920*: in the first image (Fig. 1), the point of interest (POI) is situated so that Summer's midday sun is from a slightly left angle, almost directly facing the characters. This illuminates sun-exposed actors fully but creates quite sharp shadows and high-level contrast, something that could be problematic if any important detail is in the shadows.

In the second image (Fig. 2), though the POI leaves the viewer facing the sun and the characters are situated somewhat on the right, as it is a perishing, almost golden-hour sun, it delivers not blinding but soft light which evenly illuminates the nature, props and characters. Figure 3 demonstrates how natural daylight on a cloudy day provides a uniform lighting condition but lacks a dynamic feel, resulting in a rather dim and flat image.

Fig. 2 Still Image of Wiktoria 1920 (Tomasz Dobosz, 2020)

Fig.3 Still Image of Wiktoria 1920 (Tomasz Dobosz, 2020)

Practical Lighting

Another technique for lighting in CVR is the use of practical lights which are functional and visible light sources within the scene, such as lamps, candles, or streetlights. These sources also contribute to both the aesthetic and storytelling elements of the video, while also providing a source of illumination. Using practical lights strategically can help guide the viewer's attention, create a specific mood, or establish a sense of place. For instance, a flickering neon sign may contribute to the atmosphere of a seedy urban setting. Furthermore, by altering the practical lights by covering them with coloured gels or filters, and replacing regular lighting bulbs with high-power bulbs, creators can manipulate the colour and intensity of the light, which can help to better convey the desired look (Zhang & Weber, 2021; Stuart, 2017).

The usage of practical lighting in *Wiktoria 1920*: Figure 4 demonstrates how practical lights are effectively used for illuminating the scene. Table lamps, projector, floor lamp, chandelier on the ceiling – they all feel natural, they help to set the mood, but at the same time act as necessary sources of light. Though, in this particular scene, the usage of additional dim fill light that shines through the window and glass partition, which helps to fill the room with soft diffused light, is closer to *hidden lighting* and the scene could be classified as *mixed lighting* technique, it is a good example of practical lighting as the practical lights are the key lights illuminating the faces of the actors.

Fig. 4 Still Image of Wiktoria 1920 (Tomasz Dobosz, 2020)

Hidden Lighting

When working with artificial light sources in CVR, unless the lights are part of the story, the creators need to erase the lights in post-production or hide the lighting equipment on set. For example, incorporating lights into the décor, e.g. as recessed fixtures or LED strips, or by concealing them as part of the set, e.g. a prop or a piece of furniture. Lighting equipment can be also placed behind pieces of furniture, e.g. behind a couch or cupboard. A hidden indirect light can also be reflected off objects such as walls or ceilings to provide diffused lighting (Zhang & Weber, 2021; Zhang, 2020).

The usage of hidden lighting in *Wiktoria 1920*: as part of the story, there are characters who are watching something on a projector screen, but the CVR experience creators use this large white fabric – the projector screen that is illuminated behind –simultaneously as a source for a large diffused light (Fig. 5).

Mixed Lighting

Often creators choose to use mixed lighting and combine different light sources to achieve the desired illumination and look. For example, a scene may include practical, hidden and natural lighting, with sunshine creating a warm, inviting mood and practical and hidden lights adding depth, character and fill light. Mixed lighting can also include the use of opposing colour temperatures, such as cool and warm light sources, to create visual tension or to highlight specific features in the image. However, mixed lighting requires experience and skill since the improper balance between different light sources can result in unnatural colouring or sharp contrasts between areas with different exposure levels.

The usage of mixed lighting in *Wiktoria 1920*: the primary light source in this scene (Fig. 6) is a huge light from high up that acts as a moon, providing characteristic cold [bluish] light and key illumination. To counterbalance the cold moon and for the lighting dynamics of this scene, the practical lights add fill light on a much warmer [yellower] colour temperature and help to convey the desired look and feel of the scene.

In an indoor scene in Fig. 7, the practical lights hanging from the ceiling help to illuminate the characters, but for greater illumination of the whole room, high-power light equipment is hidden behind a corner, so that the viewer sees light beaming in from the door arch, but cannot see the source of it. Mixing the natural light with practical lights is well demonstrated in Figure 8 where daylight from the window provides neutral overall light and a warm-coloured temperature floor lamp adds dynamic to the scene while also providing practical illumination.

Clean Plating and Post-production Colour Correction

In a setting where natural, ambient, practical or hidden lights are not enough and an additional light source is used that is visible in the shot, creators can remove them using a technique called *clean plating*. This means that the original scene is shot with the lighting equipment visible (Fig. 9A) and then the same scene is shot again without the visible lighting equipment (Fig. 9B). Next these two videos or *plates* are

Fig. 5 Still Image of Wiktoria 1920 (Tomasz Dobosz, 2020)

Fig. 6 Still Image of Wiktoria 1920 (Tomasz Dobosz, 2020)

Fig. 7 Still Image of Wiktoria 1920 (Tomasz Dobosz, 2020)

Fig. 8 Still Image of Wiktoria 1920 (Tomasz Dobosz, 2020)

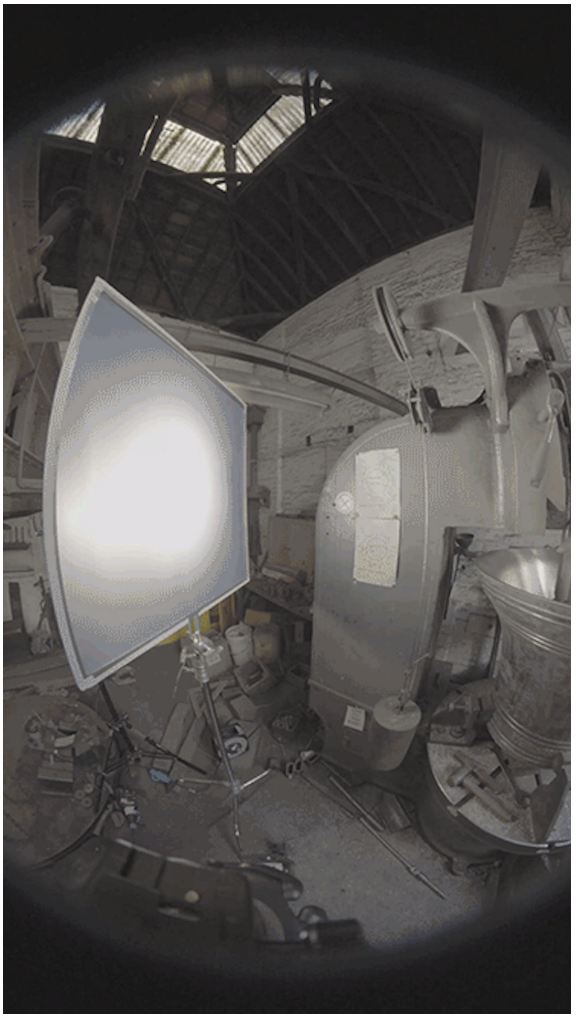


Fig. 9A Original Footage (Stuart, 2017)

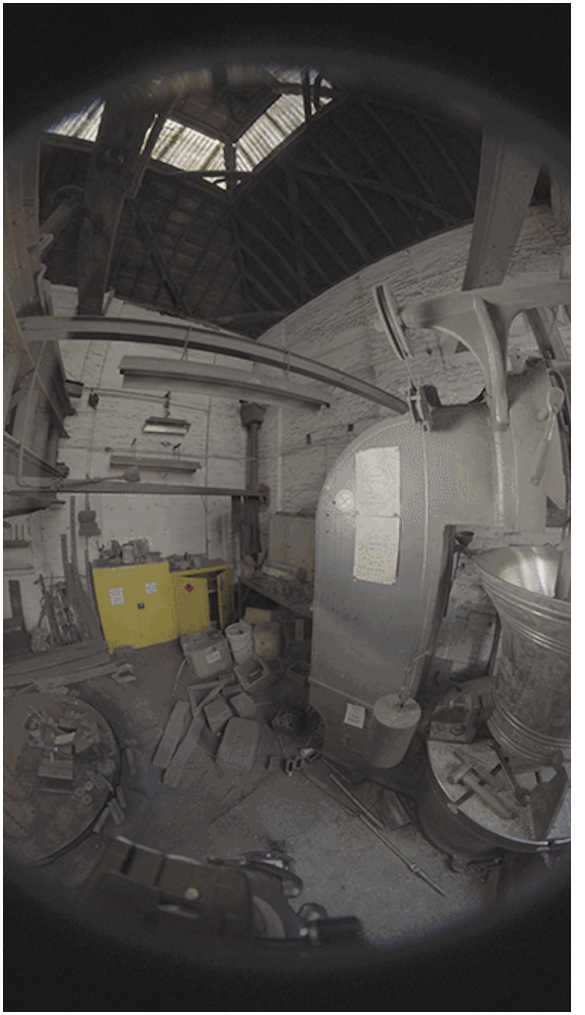


Fig. 9B Clean Plate Footage (Stuart, 2017)

overlaid in post-production and the shot without the lighting equipment can be used to mask out the lights in the original shot (Tricart, 2017; Stuart, 2017).

The specific technique employed for this process is dependent on the nature of the footage, particularly whether it involves movement or not. In cases of movement, the material is typically transferred to a graphics program such as Adobe After Effects. There, a mask of the clean plate is constructed, which is transparent in all areas of the image except where the undesirable elements of the original footage exist. This mask meticulously tracks all necessary movements within the footage, ensuring it does not obstruct any essential parts of the footage. Subsequently, this mask is exported to preferred editing software, like Adobe Premiere Pro, where the mask layer is superimposed onto the original footage.

Alternatively, if there is no movement in the areas requiring replacement with a clean plate, a still image plate might be utilised. In this scenario, a still image of the clean plate is imported into the preferred photo editing software, such as Adobe Photoshop, where a mask is crafted to be transparent in all areas except where the unwanted elements of the original footage are present. Subsequently, a still image with transparent characteristics (e.g., a PNG file) is generated and imported into a video editing program, where it is placed over the original footage to conceal all unwanted areas.

If a clean plate is unavailable, software-based solutions exist to eliminate undesired areas or objects in the footage. For instance, in Adobe After Effects, it is possible to create a mask to exclude unwanted areas and utilise the Content-Aware Fill function, which employs artificial intelligence (AI) to replace [fill] the masked region with clean footage. Though convenient, the quality of the results might vary.

Though the clean plating technique provides more freedom in lighting the set, it adds to the time spent on shooting the scene as one might need to shoot the clean plates in segments because removing all the lighting equipment at once could too drastically change the look of the scene causing the merger of footage in post-production to become cumbersome if not impossible.

Similar to the traditional film post-production procedures, some of the desired lighting can be achieved in the post-production process where creators can fine-tune and change the appearance of the video. For example, exposure can be adjusted to brighten dark regions or tone down excessive highlights. Also, the colour temperature and balance can be adjusted and with visual effects, even new digital light sources can be created or existing ones supplemented to improve the overall lighting design.

Conclusion

By delving into the invention of the stereoscope, regarded as the genesis of VR, this article illustrates that the origins of CVR trace back to the realm of still photography (which subsequently contributed to the evolution of traditional film). With 3DoF, CVR typically uses a narrative structure with a beginning, middle, and end, drawing upon the principles of traditional filmmaking, including the art of set lighting. Although both VR and CVR may employ the same HMD systems for

immersive 360-degree experiences, the user experience [e.g., VR is interactive whereas CVR is *sit and relax*] and the content creation process differ. CVR content is predominantly recorded as live-action, involving real performers and either stationary or moving objects in real-life settings, thus relying on real-life set lighting. In contrast, VR is often developed in a game engine, allowing for animated environments, characters, and objects, enabling artificial lighting through software.

As the process of crafting CVR content aligns closely with traditional filmmaking and its set lighting techniques, it is advantageous to explore and examine the relevant methods of traditional film lighting in the context of CVR. Building on this understanding can contribute to the development of CVR as an art form, aiming to achieve a high level of craftsmanship comparable to that of traditional film lighting. By shedding light on the different techniques used to illuminate CVR experiences and to achieve the desired lighting, this paper provides insights into the best practices for lighting design in CVR productions for creating immersive and visually appealing CVR content. The paper presented four types of lighting techniques – natural or ambient lighting, practical lighting, hidden lighting, and mixed lighting – and provided examples by studying existing CVR experience *Wiktoria 1920*.

The study leads to the conclusion that *Wiktoria 1920* employed all four lighting techniques mentioned earlier, following an approach akin to traditional film lighting. This implies the use of various lighting elements, such as lighting temperature, intensity, source visibility, etc., to establish the desired atmosphere. The purpose of the lighting was to generate dynamics, contribute to storytelling, and produce dynamic visuals, rather than merely serving the function of enabling viewers to see the events. *Wiktoria 1920* stands out as a trailblazer in the realm of dynamically illuminated CVR experiences, showcasing a diverse array of lighting techniques. Through the analysis of different CVR experiences, such as *Hailey 1.0* (2020), *Runway* (2019), *The Invisible Man* (2016), and *New Reality* (2015), it is evident that they likewise adhere to the fundamentals of traditional film lighting, but with a predominant emphasis on the use of natural and mixed lighting. The rationale for this could be that a) natural lighting is most easy to use and requires no additional lighting equipment, and b) mixed lighting takes advantage of different light sources available on a set [e.g. practicals] and is suitable for a scene in order to achieve the necessary level of illumination. In addition, mixing different types of light sources with different levels of illumination and colour temperature provides the creator with the opportunity to reinforce their desired visual look through lighting design.

This paper is one of the first attempts to provide a concise overview of the different approaches and techniques, as well as prevailing practices, on how to light 360-degree scenes. Further academic analysis is needed on the best practices, but also on the future possibilities for CVR in the context of lighting and the use of emerging new technological possibilities in set lighting but also in the post-production process.

References

Bordwell, D., Staiger, J., & Thompson, K. (1985). *The Classical Hollywood Cinema: Film Style and Mode of Production to 1960*. Routledge.

Bucher, J. (2017). *Storytelling for Virtual Reality: Methods and Principles for Crafting Immersive Narratives* (1st ed.). Routledge. https://doi.org/10.4324/9781315210308

Daniel Baldwin. (2020, March 11). *Hailey 1.0* [Video]. YouTube. https://youtu.be/9vqM7IHKaDc

Dooley, K. (2021). *Cinematic Virtual Reality: A Critical Study of 21st Century Approaches and Practices*. Palgrave Macmillan. https://doi.org/10.1007/978-3-030-72147-3

Felnhofer, A., Kothgassner, O.D., Schmidt, M., Heinzle, A.K., Beutl, L., Hlavacs, H., & Kryspin-Exner, I. (2015). Is virtual reality emotionally arousing? Investigating five emotion inducing virtual park scenarios. *International Journal of Human-Computer Studies*, *82*, 48–56. https://doi.org/10.1016/j.ijhcs.2015.05.004

Hugo Keijzer. (2016, July 1). *The Invisible Man* [Video]. YouTube. https://youtu.be/I_FUpUi2LBk

Katatikarn, J. (2023, March 21). *Virtual Reality Statistics: The Ultimate List in 2023*. Academy Of Animated Art. https://academyofanimatedart.com/virtual-reality-statistics

Mateer, J. (2017). Directing for cinematic virtual reality: How the traditional film director's craft applies to immersive environments and notions of presence. *Journal of Media Practice*, *18*(1), 14–25. https://doi.org/10.1080/14682753.2017.1305838

Moody, P. (2017). An 'Amuse-Bouche at Best'. *International Journal of E-Politics*, *8*(3), 42–50. https://doi.org/10.4018/ijep.2017070104

Niepodległa. (n.d.). *Film VR "Wiktoria 1920" online*. The Office of the 'Niepodległa' Program. Retrieved March 26, 2023, from https://niepodlegla.gov.pl/o-niepodleglej/film-vr-wiktoria-1920-online

Owl VR. (2015, December 21). *New Reality* [Video]. YouTube. https://youtu.be/AURjAl5YaRE

Rakkolainen, I., Raisamo, R., Turk, M., & Höllerer, T. (2018). Illumination for 360 degree cameras. *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology (VRST '18), USA*, *Article 96*, 1–2. https://doi.org/10.1145/3281505.3281589

Ross, M., & Munt, A. (2018). Cinematic virtual reality: Towards the spatialized screenplay. *Journal of Screenwriting*, *9*(2), 191–209. https://doi.org/10.1386/josc.9.2.191_1

Sentium Media. (2019, April 21). *Runway* [Video]. YouTube. https://youtu.be/Los4U2pZLiE

Stuart, H. (2017, April 6). *360 production tips – how to light a shoot*. Visualise. https://visualise.com/2017/04/lighting-360-video

Säks, E. (2022). Using Cinematic Virtual Reality to Get Acquainted with the Metaverse. *Baltic Screen Media Review*, *10*(2), 252-271. https://doi.org/10.2478/bsmr-2022-0019

Tong, L., Lindeman, R.W., & Regenbrecht, H. (2021). Viewer's Role and Viewer Interaction in Cinematic Virtual Reality. *Computers*, *10*(5), 66. https://doi.org/10.3390/computers10050066

Tricart, C. (2017). *Virtual Reality Filmmaking: Techniques & Best Practices for VR Filmmakers* (1st ed.). Routledge. https://doi.org/10.4324/9781315280417

Vosmeer, M., & Schouten, B. (2017). Project Orpheus A Research Study into 360° Cinematic VR. *Proceedings of the 2017 ACM International Conference on Interactive Experiences for TV and Online Video (TVX '17), USA*, 85–90. https://doi.org/10.1145/3077548.3077559

Wade, N.J. (2012). Wheatstone and the origins of moving stereoscopic images. *Perception*, *41*(8), 901–924. https://doi.org/10.1068/p7270

West, N.M. (1996). Fantasy, photography, and the marketplace: Oliver Wendell Holmes and the stereoscope. *Nineteenth-Century Contexts*, *19*(3), 231–258. https://doi.org/10.1080/08905499608583425

Wheatstone, C. (1838). Contributions to the physiology of vision – Part the first. On some remarkable, and hitherto unobserved, phenomena of binocular vision. *Philosophical Transactions of the Royal Society*, *128*, 371–394. https://doi.org/10.1098/rstl.1838.0019

Wheatstone, C. (1852). Contributions to the physiology of vision. – Part the second. On some remarkable, and hitherto unobserved, phenomena of binocular vision (continued). *Philosophical Transactions of the Royal Society*, *142*, 1–17. https://doi.org/10.1098/rstl.1852.0001

Zhang, Y. (2020). *Developing a cinematic language for VR filmmaking* [Doctoral dissertation, Griffith University]. https://doi.org/10.25904/1912/4021

Zhang, Y., & Weber, I. (2021). Adapting, modifying and applying cinematography and editing concepts and techniques to cinematic virtual reality film production. *Media International Australia*, *186*(1), 115–135. https://doi.org/10.1177/1329878x211018476