DIRECTING AUDIENCE ATTENTION:

CINEMATIC COMPOSITION IN 360 NATURAL HISTORY FILMS

by

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ABSTRACT

Since cinema's creation, the standard format for viewing video content has been a flat, planar image projected onto a screen. The recent invention of the 360-film format allows for a panoramic view of a spherical visual video surface. Cinema composition is a series of aesthetic tools and processes that support a visual framework that filmmakers utilize during production. Composition choices in filmmaking help direct the audience's attention to the most important aspects of each scene. 360 formats in natural history filmmaking defy some of the conventional cinematic standards that have been in place since the early development of cinema production. These differences are due to the larger field of view in 360 filmmaking, which is created by the panoramic, equirectangular shape of 360 video. Through case studies of 360 natural history films *My Africa*, *Expedition Everest*, and my production *You Are Here: National Parks in 360*, this paper examines how the 360-film format has affected composition choices in natural history filmmaking and analyzes the 360 conventions used to direct audience attention in alternative cinema formats.

CHAPTER ONE

INTRODUCTION

The natural history genre of documentary film tells stories of our natural world (Bousé 2000). Exotic destinations, wildlife behavior, and the natural cycles in nature are common themes. These stories often show the power, beauty, and majesty of nature to connect viewers with our world in ways that promote education through entertainment. Many documentary films use visual storytelling to immerse audiences through engrossment in the visual image with a nonverbal style, otherwise known as spectacle (Louson, 2018, Haywood 2007). Cinematic composition and the development of novel film formats push the boundaries of cinematic expression in documentary films.

Advanced in camera equipment and video playback devices has allowed filmmakers to achieve heightened immersion in the visual image. Cinema technology is continuously improving to provide increases in efficiency while maximizing the resolution, aspect ratio, and size of our multimedia screens. Whether it is upgrading to the newest smartphone, a new TV system, or the latest gaming console, consumers do not want to feel behind the curve with outdated electronics. Movies in the theater are projected on fifty-foot screens, with IMAX films shown on seventy-two-foot expanses. Sixty-five inches was the most common size for a home TV bought in 2020 (Wilcox, 2021). Phone size and resolution have increased to squeeze every last inch of the viewing experience out of our entertainment on-the-go.

The standard format for viewing online video content is a flat, rectangular video with a 16:9 rectangular aspect ratio and a frame rate of 24 or 30 frames per second. Most consumer electronics have playback with resolutions between 1920x1080 pixels (HD) and 4096 x 2304 pixels (4K). The number of pixels can determine the quality and details present in a video. A high pixel count produces an image with greater definition and resolution. This progression of expanding our electronics' size is a psychological and revenue-driven desire to feel increasingly immersed in today's video-driven world. The development of novel film formats such as 360 and Virtual Reality can be interpreted as a way to enhance immersive entertainment media.

Multimedia formats such as 3D, 360, and VR+, that differ from the standard flat video formats are a specialized entertainment sector. These formats seek to replicate our ocular experience of the real world (Gödde et al., 2018). The development of 3D video mimics the depth perception that our eyes and brain utilize for spatial awareness and creates a closer-to-reality simulation within digital media (Bichlmeier et al., 2007). For example, Planetarium and IMAX domes create a projection experience for surround-video immersion. 360 and Virtual Reality video formats use a spherical projection where a person's point of view occupies the space within a sphere's interior (Corbillon, 2017). These different types of screens and projections of video media attempt to replicate a more authentic human visual experience. While traditional documentary filmmaking has often been described as providing spectators with a ”window on the world,” 360/VR+ media allow viewers to step into the digital world, where they control the frame.

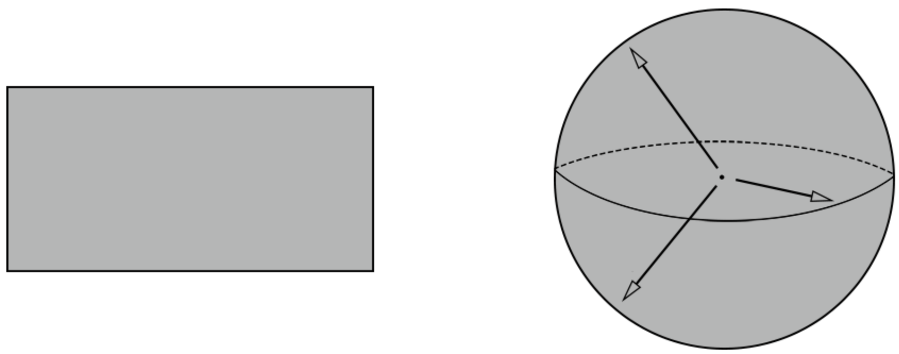

Figure 1. Playback visualization for standard, flat rectangular video formats (left), and spherical 360/VR+ video formats (right)

The introduction of non-planar formats in planetariums, VR+, and 360 content has rewritten the ways filmmakers capture, edit, and display immersive digital content. The technology required to capture a larger field of view has changed how cinematographers use the cinematic conventions of space, lens angle, framing, camera height, and camera movement. The most significant issue presented by this larger field of view is the propensity for the audience to miss important elements within a 360 scene. This is because the entire spherical surface is not visible to the viewer at all times. A portion of the 360 sphere is visible on screen, and a user must tilt or rotate the 360 video to alter the visible playback region. Directing the audience's attention in larger fields of vision than planar formats requires filmmaking techniques beyond the conventions of standard cinematic composition.

In this paper, I will first define conventional cinematic composition and discuss its use across the natural history genre. I will then analyze the 360 natural history films *My Africa* and *Expedition Everest* to examine the techniques they used to focus a viewer's attention within the

360 field of view. I use the composition choices in My Africa and Expedition Everest to identify and derive new composition techniques that are specific to 360 natural history film formats. Finally, I will discuss how I have applied these composition choices to help direct audience attention in my 360 film *You Are Here: National Parks in 360,* created in partial fulfillment of a Masters of Fine Art in Science and Natural History Filmmaking.

CHAPTER TWO

THE IMMERSIVE REALM

Virtual Reality and 360 videos are some of the latest developments in video technology in the pursuit of emulating human visual processing. These video formats allow for an unobscured 360 panoramic view, which attempts to replicate our eyes' ability to survey our surroundings (Agtzidis et al., 2019). *True virtual reality* uses aspects of computer-generated imagery to create a digital framework or to enhance existing 360 video (Wilk, 2019). In contrast, 360 video can be defined as media that is filmed *in situ* and transformed into a spherical panorama (Wilk, 2019). 360 film refers to the documentary and narrative film formats, which use a multiple-lens camera to capture a 360 field of view at a location. The 360 format was first developed as still images back in 1857 by M. Garrela of England, where landscapes were photographed as a panoramic image in a long, rectangular format (Lai, 2020). Today, 360 video utilizes a similar equirectangular format with digital stitching to wrap the seams into a sphere.

For the sake of separating the types of video and media playback platform into defined categories, I am grouping all the flat, rectangular media into the category of *standard video* format, all the 360-captured media into the category of *360*, and the Virtual Reality with interactive elements inside the video playback into the category of *VR+*.

Figure 2. Equirectangular 360 video. The equirectangular video distorts objects at the top and bottom of the sphere in a rectangular projection. Notice that a vehicle split in half along the left and right edge of this rectangle. The edges of this equirectangular video will be digitally joined to create a globe-projection out of this flat surface area.

One of the significant differences between 360 video and the many branches of VR+ is the idea of passive viewership in 360 media. Passive viewership is defined as observing film content without additional interactivity requirements (Modrak & Anthes, 2010). 360 content has moving elements, and a user can alter their relative body position to view the media. However, they cannot move in three-dimensional space within the experience; rather, they are restricted to the fixed location at the spherical projection center. Active viewership requires the user to click, select, or interact with objects within the VR+ viewing experience (Gödde et al., 2018). In some VR+ content, users are not restricted to a singular static location, and can move around or past objects in the digital space. According to Wilk (2019), “true Virtual Reality is focused more on gameplay and interactivity in addition to the visual aesthetics.” This dichotomy in interactive potential is what makes 360 an outlet for documentary storytelling, while VR+ programs are more often geared towards gaming-based entertainment.

Recently, 360 and VR+ content has become more prevalent and accessible to the general public. VRChat is a popular VR-based entertainment program for users to create social connections within the digital world-building program. Facebook 360 has VR+ and 360-based services for meetings and interacting with other users within a virtual location. 360 vacations are offered in prominent places and landmarks to create the visitor experience of destination travel without the physical departure from geographical location. VR+ media is being used for healthcare training and exploring places that humans cannot readily access, like the microscopic realm and distant landscape of outer space. Despite the increase in platforms and programs that run 360 and VR+ content, additional hardware is required to interface with 360/VR+ media.

Understanding VR360 Playback Devices

Interfaces with VR and 360 media are typically viewed through three types of playback devices: computer screens, smartphone screens, and VR headsets (Boas, 2013). Computer screens include laptop and desktop computers, where clicking and dragging the mouse will reorient the viewer's directional perspective inside the 360 field of view. Smartphone screens include phones, tablets, and devices that use these portable electronics as the primary playback device, such as Google Cardboard (Vailshery, 2021). VR Goggles have wearable VR 2-lens goggles which interface with a computer or entertainment system such as Oculus. While the media playback remains the same, the way viewers interact with the media is very different across these playback platforms.

Desktop and laptop computers are widely available to the public, but they are least optimal for VR+ and 360 playback for two reasons. First, most computers do not have a gyroscope sensor that enables motion detection like those in smartphones, which enable the interface of the device's orientation with the video playback direction in 360 formats (Blum et al., 2013). Lacking this senor limits a computer's functionality with 360 media. Second, projecting a spherical surface area onto a rectangle creates inaccuracies similar to the size discrepancy of countries on the Mercator-projection world map (Yu-Chaun & Grauman, 2017). In other words, the main drawback of viewing 360 media on a computer screen is the imperfect projection of the spherical video on a flat-screen, which becomes apparent the further from the horizon that the playback is angled.

Smartphones are an improvement over computer devices in the playback navigation of 360 content. The handheld nature of these devices creates less obvious projection issues and allows for rapid changes in the field of view. The projection of the spherical 360 films onto a flat rectangular plane is still a factor, yet the subtle directional changes in pan and tilt of the device are recognizably smoother in playback. This playback represents a field of view that the user can change by raising and lowering their device, tilting, or rotating their body in 3D space (Carvalho, 2018).

Google Cardboard creates the sensation of viewing 360 content through VR goggles, without the expensive hardware upgrade. Developed by Google in 2014, the VR Goggles were created to encourage the development of VR applications and provide consumers a preview of the new media format (Vailshery, 2021). The New York Times assisted with the distribution of over a million Google Cardboard units with an accompanying 360/VR+ film called *The*

Displaced (Somaiya, 2015). Google Cardboard and similar devices retrofit a smartphone with two optical lenses and a case, which a user holds up to their eyes. It is a low-cost version of VR goggles. The lenses are magnifying glasses, not LCD screens as in *true VR* goggles (MacIssac, 2015). Google Cardboard devices create a stereoscopic view by splitting the smartphone screen into two side-by-side videos. By placing the smartphone into the Cardboard device and viewing through the dual lenses, the two videos optically merge into one stereoscopic video (Patterson, 2017). While devices like Google Cardboard do not have the resolution and playback capabilities of *true VR* goggles, their form and function are similar (Wilk, 2019). Consumers who want the full experience of high-resolution 360/VR+ content that is associated with gaming and social entertainment will need to upgrade their Google Cardboard for *true* VR goggles.

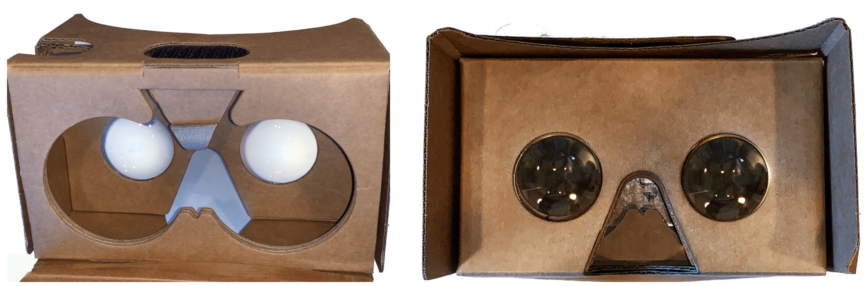

Figure 3. Google Cardboard. The low-tech VR goggles place a smartphone against the front (left), and viewers watch through the lenses on the back (right).

Figure 4. YouTube Google Cardboard Playback. Viewing the 360 video through YouTube's app on smartphones with the Google Cardboard. The screen is split into two playback videos that optically merge when viewing through the magnification lenses.

VR goggles are the most expensive form of VR-specific playback devices (Papachristos, 2017). These devices connect to a computer or entertainment system via wired or wireless playback. The goggles use a two-lens ocular screen playback that encompasses the viewer's entire field of view, blocking out all visual cues outside the goggles (Boas, 2013). Although goggles come in several forms and resolutions, they all aim to deliver 360 and VR+ devices' immersive visual experiences (Papachristos, 2017). Viewers navigate the projected playback video with a limited field of view at any given moment and shift their body and head position for scene playback directionality (Boas, 2013; Carvalho, 2018). Due to the blocking out of the person's surroundings for immersive playback, some individuals have issues with the sensation of motion and the inner ear equilibrium during playback (Akizuki et al., 2004). Technological devices for viewing 360/VR+ videos have made advancements in optical resolution, spatial sound playback, and even facial-emotive tracking as they try to simulate reality through virtual-immersive experiences (Gödde et al., 2018; Suzuki, 2017).

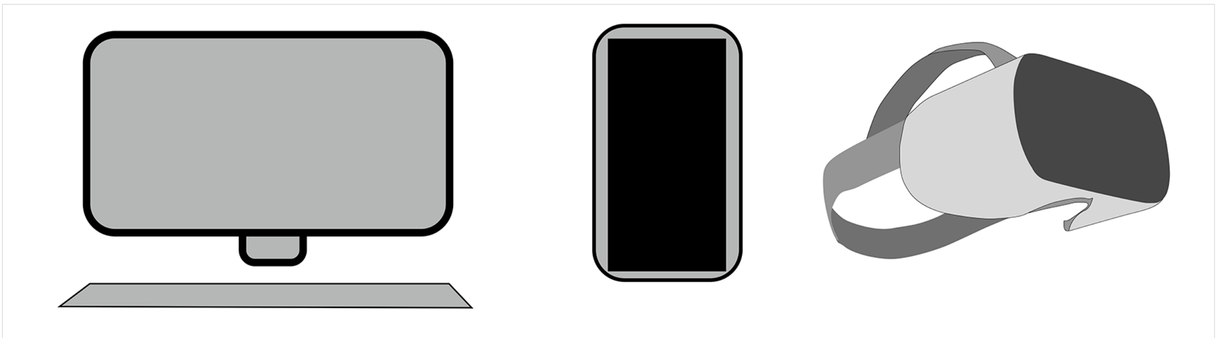

Figure 5. Playback Devices for 360/VR+ include the desktop or laptop computer (left), smartphone or tablet (center), and VR Goggles (right).

360 equirectangular videos require digital stitching into spherical projections to view. This is accomplished through software available on specific websites. 360/VR+ devices depend on a software platform to recognize device playback position and rotation to alter the video playback's real-time orientation. If a 360 video is uploaded on a website that does not have the ability to transform the equirectangular video into a stitched 360 panorama, the video will only appear as a rectangular video.

YouTube, Vimeo, Facebook, Google, and dozens of other websites host VR+ content that is available for consumer audiences. A 360 video that is uploaded to YouTube can be viewed in 360 on smartphones, desktop computers, and across multiple VR Goggle brands that have access to the YouTube website. However, not all VR+ content can be viewed across all playback devices. VR+ content that requires additional features may require VR goggles that integrate with keyboards and joysticks. Because of this, some content like gaming and exercise programs in VR+ is developed to only play via VR goggles and is not available on smartphone playback devices.

Regardless of acquisition process or playback design, 360 video and VR+ content have elements, requirements, and functionality that assist viewers in navigating the unique video format. All video mediums share a set of principles guided by camera technical specifications and cinematic styling to create visual experiences for their audiences. Composition is a powerful tool for filmmakers to craft visual expression and is accomplished through choices in production and post-production. These elements of film composition and their impact on the audience are the focus of the next section of this paper.

CHAPTER THREE

COMPOSITION IN CINEMATOGRAPHY

Composition is one of the basic principles of cinematography. Deciding what to include and exclude within the camera's visual frame in every single shot is composition (Rabiger, 2015). It has developed and changed over time to become a set of principles and techniques for achieving visually pleasing viewing experiences. In Michael Rabiger's book *Directing the Documentary*, he describes composition as a tool for the audience to be emotionally influenced by the cinematic choices determined by the director,

> “shots with a camera reproduce aspects of human regard, which can be short or long, causal or intense, with thoughtful framing, composition, and context you can inflict each shot with special meaning, because a particular shot often implies the thoughts and feelings of whoever is doing the seeing” (Rabiger, 2015, p.78).

The camera is a tool to capture the artist’s cinematic point of view. We can associate the camera lens to the likeness of the human eye as to how it receives visual data. Our brain then interprets the visual information to inform meaning (Rabiger, 2015). Establishing a film's purposeful point of view relies on the core concepts of what is and isn't included within the frame.

Composition is created through the specifications of equipment and the human brain's perception of spatial awareness. In his book *Picture Composition for Film and TV*, Peter Ward describes composition as providing, “an agreeable visual experience independent of the purpose of the shot” (2003, p. 11). The camera dictates the techniques for composition– “whenever a camera converts a three-dimensional subject into a two-dimensional picture, the imprint of the lens height, camera tilt, distance from subject, and lens angle is present in the composition of the shot" (Ward, 2003, p. 7). The essential elements of composition that influence perspective in the production stage of filmmaking are camera height, lens length, vantage point, and camera angle. These influencing factors for composition and interpretation in cinema inform the aspects of camera specifications that determine the audience's interpretation of a scene (Ward, 2003).

Composition works to create an atmospheric mood for the visual storyline when non-spoken elements which communicate information to the viewer through the specific composition of shots (Ward, 2003). Further, the progression of individual shots into sequences of composed imagery influences the overarching narrative. If the filmmaker is to tell a cohesive story through cinema, "the unobtrusive compositional elements in the transition from shot to shot must be invisible to the audience, yet understood provided the pace of the film, the resulting action, and the variety of visual elements" (Ward, 2003, p. 5). The filmmaking aesthetics of composition are "employed to solve the perennial questions of what does the audience need to know, how will they be told, and at what point in the production should they be told" (Ward, 2003, p. 54).

Camera composition influences the impact of a story on the viewing audience through selective focus. The compositional elements that affect narrative focus include, "lens focal length, lens F/stop, camera height, camera distance, camera angle, detail and resolution, lighting conditions, filters, image size when viewed, viewing conditions, subjective context and cultural influences" (Ward, 2003, p. 27). Filmmakers also use the elements of composition to direct attention to specific regions of the field of view to emphasize important factors.

Camera specifications and placement aren't the only factors that affect the overall composition of a film. Elements of composition that are not camera-specific include production lighting, synch sound, music, and post-production special effects that work together achieve a filmmaker's desired visual impact and directs the viewer’s eyes to specific regions of the frame. These essential cinematic compositional tools affect how viewers experience films in both standard and 360 formats. In the following chapter, I analyze how composition is used in natural history filmmaking and how those cinema choices affect the visual experience.

CHAPTER FOUR

COMPOSITION IN NATURAL HISTORY FILMMAKING

Natural history filmmaking is a form of documentary cinema devoted to "reconnecting people to nature, captivating large audiences with entertaining and emotionally charged story-lines" (Fernández-Bellon & Kane, 2019). Composition techniques in cinema production creates strategies for natural history filmmakers to create perspective in film and connect viewers with our natural world. The development of new technologies pushes the boundaries with compositional elements of lens length, camera location, and manipulation of the perception of time to tell natural history stories that immerse the viewer in nature in ways that the average human would not experience (Kasic, 2007).

> "Over the course of time, these new technologies have influenced what viewers are willing to accept as being authentic in the context of representations of the natural world. Time-lapse or slow-motion sequences, infrared or heat-sensitive imaging, the extreme close-ups of macrophotography – all of these have become accepted means of portraying the reality of the plant and animal kingdoms, even though they show aspects of nature that would not normally be visible to the naked eye." (Scott, 2003, p.31).

Innovation in camera technology provides filmmakers with the ability to capture nature in ways that humans rarely experience first-hand. In the BBC landmark natural history series *Planet Earth*, filmmakers used advanced camera technology to capture the spectacle of natural landscapes and animal behavior. High-speed Phantom cameras by Vision Research captured 25,000 FPS of slow motion. Manipulating the playback speed and spatial layout within the frame impacts the audiences' perspective of nature to reveal behavior and processes that are impossible to see with our own eyes (Kasic, 2007). Cameras mounted on drones and helicopters allow filmmakers to capture "extreme close-ups, long shots, and slow-motion and in challenging, even prohibitive, conditions play a significant role in creating the ‘epic’ and ‘heroic’ style that the filmmakers envision” (D’Amico, 2013). The 3D immersive IMAX film *National Parks Adventure* composed shots from high vantage points to film climbers ascending rock faces in Yosemite National Park and Devils Tower National Monument. The innovative “Wall Pod” was developed to ascend with the climbers. Special helicopter-mounted “SpaceCams” were used in Utah's desert to give viewers the experience of flying over Moab from the birds' perspective (National Parks Adventure, 2016). Developing camera systems that change the vantage point helps create new perspectives in natural history films.

Depth of field is a composition tool, which directs attention to most essential subject matter by reducing the regions of focus within the frame. (Modrak & Anthes, 2010). Filmmakers use depth of field as a technique to manipulate the region of sharp focus. Depth of field is achieved in production through manipulating the amount of light that passes through the iris of a camera lens. A large aperture results in a large region of blurred field of view. In scenes with animal subjects, a very shallow depth of field (large aperture), makes a subject stand out in sharp focus while blurring the background's less-important objects. For landscape shots, a deep depth of field (small aperture), captures the entire area in sharp focus. This helps to establish a sense of location and terrain for the film as a setting for the following scenes.

Natural history films create perspective through manipulating the composition choices of camera lens length and vantage point. A long lens length increases the detail of distant objects and provides audiences a deeper connection to the subject (Kasic, 2007). A wide lens length creates a better understanding of the subject-camera relationship and to the subject and within the surrounding landscape (Kasic, 2007). A camera height can help audiences interpret the story from a human's perspective, a bird's-eye perspective, or a bug's eye view of the world. Bird's-eye perspective can reveal truths through the “bigger picture,” while a bug's-eye view can create intimacy between the viewer and the subject (Kasic 2007). This reevaluation of the lived human perspective in natural history films does, “not just *reveal* the natural world via an expansion of vision; they also work to *change* viewers’ affective responses to nature (Hovenac, 2019, p.246).” The camera,

> “with all its resources for swooping and rising, disrupting and isolating, stretching or compressing a sequence, enlarging or reproducing an object,” allows us to “discover the optical unconscious”—the things that always occur before our eyes but that we do not consciously register. It is another nature which speaks to the camera as compared to the eye” (Hovanec, 2019, p.266).

Camera location is one of the two most critical compositional decisions in filmmaking. The camera's location to the primary subject matter's proximity creates what is commonly referred to as shot size. In a study by Rothe, Sarakiotis, and Hußmann (2019), researchers determined the approximate distance for shot size in reference to personal spatial relation zones. The shorter distance between the camera and the subject, the more personal and emotional the connection (Rothe et al., 2019). With increasing distance to this axis, the subject's impact for narrative substantiation is reduced from more to less importance as it transitions from close proximity to infinity (Rothe et al., 2019). The composition choices of camera height, location, and lens length help establish selective focus, directing the audience's attention in natural history films.

Shot duration in cinematic composition helps determine the tone and beats of a scene (Ward, 2003). Similarly, tracking shots via drone or Steadicam systems allow a viewer to travel with the action in a scene without cutting in-between. Steadicam and other similar camera stabilization devices reduce camera shake that occurs when a camera is carried over irregular terrain. The stabilization of moving camera footage allows filmmakers to follow action without cutting in between takes. The use of long takes and tracking shots is becoming more common practice in natural history film according to Vox's analysis on the Hollywood cinematic influence on documentary composition (Vox, 2017, 3:50-5:21). By following a single subject in a scene, the filmmaker directs audience attention to the subject in movement and places less emphasis on the other objects in frame.

In many natural history films, the camera often captures the splendor of nature, while simultaneously creating the illusion of the world devoid of human-made elements such as roads, power lines, and human inhabitants are excluded from the image for the embodiment of timelessness and dramatic or suspenseful storylines (Bousé 2000). Removing humanity's presence from the field of view involves the compositional choices of camera placement, camera height, lens length, and vantage point. Limiting the appearance of humanity's impact on the natural world is a common theme in blue-chip natural history documentaries (Louson, 2018). These compositional choices affect the audience's perception of the natural world and overall cinema experience.

Leading lines, the rule of thirds, and the golden ratio are aesthetically pleasing composition techniques in rectangular video formats (Ward, 2003). These techniques use elements like symmetry, positive and negative space, along with tools like lens length or camera angle to determine where to place subjects in the frame (Rabiger, 2015). Aesthetically pleasing composition within the frame of a shot directs the eyes of the viewer to what the filmmaker wants them to focus on. Shot size, vantage point, and headspace are all elements of filming live subjects in documentary films, while horizon line, leading lines, and rule of thirds can be conceptual tools for wide-angle landscape shots (Ward, 2003). Most natural history films use composition techniques for standard video formats, however, these elements do not always translate into composition that can be useful for 360 film formats.

With the development of 360 formats for natural history filmmaking, a director needs to consider composition choices for a larger field of view. No longer can a director think of the image as a “window on the world” or define the film's tone and storyline by shot size and exclusion of visual information outside the frame. With a 360 field of view, a viewer has the option of changing their perspective to explore in all directions. To keep the viewer from missing important details in a film, a filmmaker must choose composition techniques that will direct the eyes of a viewer to the important region of the 360 playback surface. In the following chapter, I outline the cinematic composition choices in 360 natural history films via case studies on *My Africa*, *Expedition Everest*, and my film *You Are Here: National Parks in 360*.

CHAPTER FIVE

CASE STUDY: MY AFRICA

The strategies and elements that characterize composition in natural history filmmaking are not always applicable to 360 formats. For instance, long lenses for filming wildlife and landscapes from considerable distances are replaced by wide-angle, fisheye lenses that capture the entire 360 surroundings. Shot size is emphasized by placing the main subject close to the camera lens, instead of relying on framing a character within a rectangular field of view. A character's engagement with the audience depends on where they are placed in the 360 field of view, and how they occupy that space. Used effectively, composition helps direct the viewer's attention to what is important and away from distracting elements within the expanded field of view. In this chapter, I analyze how Conservation International used composition to direct audience attention in the 360 natural history film *My Africa* (Conservation International, 2018).

My Africa begins with a male lion several meters from the camera location, placed near the horizon line. The fisheye nature of 360 cameras creates the illusion that this lion is more distant than he is in reality (Xiong & Turkowski, 2002). The camera height places equal emphasis on the sky and ground, so the horizon is at zero degrees. The film is shot with a zero-degree camera angle relative to the horizon line, which helps keep the horizon constant when panning or tilting the playback device. The lion is the only object close to the camera, creating a focal point that draws the viewer's attention. These choices work to replicate the sensation of being present at the camera's location, as they are parameters similar to our own visual experience.

A few seconds into the film, a jump-cut transports the viewer to a herd of African elephants. A young elephant is next to the camera, but below the horizon line of the frame. There are other elephants in this shot, but the young elephant's proximity and direct interaction with the camera pull the viewer's attention more than the distant adult elephants. However, the viewer has to angle their playback device to look down to see the elephant. While this action mimics real-world scenarios of tilting and panning our heads to survey in 360 directions, the action could be missed if the viewer is not actively searching for objects beyond their current frame of perspective.

The film's shot lengths are determined by the duration of the action, instead of being based on how long it would take a viewer to survey the entire 360 view. The film also does not have a standardized compositional direction, which would help the viewer return to the same direction in subsequent clips to locate the most important action event within a 360 video. While the length of a shot helps increase or release the tension in filmmaking, if the shot duration is not adequately long, a viewer can miss important action while exploring other directions in the 360 field of view. For example, wildebeest are moving in a herd down into a river and up the nearby bank. The presence of wildebeest in all 360 directions is a potential obstacle for focusing viewer attention to one area of the playback surface. Therefore, if a lion attacks a wildebeest, the viewer is likely to miss the event in case their attention is not focused in that specific location. Conservation International directs attention to this action event first through narration, which foreshadows danger and then shows the lion before the kill, then by using sufficient shot duration for a viewer to locate the lion before the attack.

Throughout the film *My Africa*, the camera location is mostly stationary. A stationary camera position allows the viewer to rotate on an axis without a constantly changing reference location. While a static camera position is not as dynamic as a moving camera, in 360 formats the effect is the decreased potential for vertigo due to motion sickness. This film has one moving camera shot in an unusual composition choice, where the camera follows goats through a local village. While tracking shots have become more common in natural history films, the choice of including a singular tracking shot in this film neither detracts from, nor does it measurably increase this singular shot's effectiveness (Vox, 2017, 3:50).

The directors of *My Africa* used camera height, camera angle, aperture, camera location, and camera movement to tell the story from the first-person point of view. The filmmakers made compositional choices that focused a viewer's attention on the animals or people that moved within the frame. Yet, these are not the only possible ways to direct audience attention in this 360. In fact, it might be approached differently by using longer shot lengths, incorporating a reference direction, and reducing the angles a viewer has to tilt their playback device to see some of the action events unfolding. Overall, the composition choices in *My Africa* highlighted a story that was driven by animal behavior. To analyze composition choices for a 360 natural history film centered around the landscape as the main subject matter, I chose the two-part film *Expedition Everest* by National Geographic.

CHAPTER SIX

CASE STUDY: EXPEDITION EVEREST

The immersive storytelling aspect of 360 media places audiences directly into the physical location of the film. The adventure-travel genre of 360 films has become increasingly popular with large and small studios. In the case of the two-part series *Expedition Everest* by National Geographic, 360 natural history filmmaking gives audiences the experience of exploring the tallest mountain in the world, Mount Everest. The backdrop of the Himalayan Mountains is one of the main characters of this film.

In the episode *Expedition Everest: The Mission* (National Geographic, 2020a), the film begins on-location where mountains, a Buddhist temple, and "expedition climbing lead" Pete Athens are visible. The camera height in this first scene creates an unusual perspective. Athens' head is below the horizon line. This perspective places more emphasis on the mountain surroundings than if the camera height were at the human eye-level. Elevating the camera helps focusing more attention on the mountains, which are now at the same level as the lens. This appears to represent that the terrain is the main subject, rather than the film's human characters, which are below the lens level. The distance between the camera and the human subject also highlights the mountain landscape over the human presence. This helps explain the unusual camera height perspective at the beginning of the film. Additionally, time-lapse is used in two scenes in the film to show people's actions and the passing of clouds at a basecamp on Everest, displaying changes in the landscape that would otherwise be imperceptible.

Expedition Everest uses the post-production inclusion of text on the screen to help direct viewers' attention in the 360 field of view. However, it is not always used effectively to direct attention to the scene's most important aspects. In the first clip, the words “Pangboche Nepal 13,075 ft” appear on the screen. While this text helps establish the setting's location, the direction the text appears in is the least-scenic area of the field of view. This directed attention away from the opposite mountains was likely chosen not to obscure the view, compared to direct attention to the area due to aesthetic-qualities. In the following scene, the words “Base Camp 17,300 ft” direct the viewer's attention to the scenic vista of mountains and away from the hikers in the opposite direction. This is another example of why I believe the film's primary focus is on the landscape, compared to character centric.

Camera height and camera location are essential compositional elements for creating a relationship between the film character and the viewer in these 360 natural history films. In the Khumbu Glacier scene of the film, climbers are practicing ascending ladders. The camera height is halfway up the height of the ladder, instead of being at the top or at the bottom. This, combined with the camera distance, allows the action to unfold close to the horizon line. Placing the action on the equatorial horizon enables the viewer to watch the events without assuming an increased playback angle to view the action. The camera distance and height combine to make the viewer feel they are a character within the film, passively observing people around them.

In the episode *Expedition Everest: The Science* (National Geographic, 2020b), the film focuses on scientific data collection in the high-altitude environment. The compositional techniques are similar to those in *Expedition Everest: The Mission*. This episode focuses more on the specific researchers and has defined camera height, distance, location, and movement for the people within the film. The camera height appears to be the same as the biologist on camera, Tracie Seimon. When she is standing, the camera is at roughly her eye height. When she is crouching near the camera location, the camera height is shorter to accommodate her height reduction and bring the viewer to her level. This causes the audience to mirror her actions, accentuating the personal connection between the film character and the viewer (Gillespie, 2020; Aitamurto et al., 2018).

The directors of *Expedition Everest* used compositional techniques to bring viewers into the Everest landscape. The camera position is stationary throughout the film, allowing viewers to survey the landscape without a constantly changing reference point. The shot duration enables users to explore the entire view without missing important information. The appearance of text on the screen helps direct viewer's attention, even though sometimes it appears in locations that did not need emphasis. While the camera height and distance are often incongruent with human eye-level, the chosen camera height emphasizes the importance of personal connection between the on-screen subject and the audience.

To conclude, the composition choices made in *Expedition Everest* and *My Africa* work to direct viewers' attention to specific regions within their 360 field of view. The filmmakers' use of static camera position, camera height positioned at relative human eye level, and a camera angle at zero-degrees relative to the horizon are aspects that I emulate in my 360 natural history film. In my documentary film, I also used text on-screen to direct viewer attention to the landscape areas I think are the most scenic.

360 cinematography is a novel format of natural history filmmaking, which is still developing its own cinematic language. This is evident in my analysis of the case studies *My Africa* and *Expedition Everest*. While both films used composition to direct audience attention, they achieved this goal in different ways. Tracking camera shots, framing that placed the camera

at the same height as the main characters, and on-screen text are just a few examples of how both films directed attention within the 360 field of view. I have used these documentary films' approaches to craft the composition of my film: *You Are Here: National Parks in 360*. In the following chapter, I will show how these composition conventions should become standard guidelines for future 360 natural history films through an analysis of my film.

CHAPTER SEVEN

CASE STUDY: YOU ARE HERE

I created the film *You Are Here: National Parks in 360* to emulate the experience of being physically present in a National Park while being virtually distant. This project was completed as part of the degree work in the Science and Natural History Filmmaking MFA program at Montana State University. Our parklands' natural beauty is emotionally moving and has sparked inspiration in artists and filmmakers since the first American National Park Yellowstone was signed into existence on March 1, 1873. Each park's landscapes and ecosystems are dynamic and change from different weather conditions, different seasons, and environmental and human-fueled impacts like Climate Change. This film aims to capture landscapes of Glacier National Park, Yellowstone National Park, Grand Teton National Park, and Badlands National Park.

Overlooks and scenic pull-offs in National Parks are designed to provide visitors easy access to a scenic vista or focal point. In my experience, they aren't designed with a complete panoramic vista in mind. I created a 360 film to replicate the option that visitors have of taking in more of the field of view than the average 16:9 format film provides in perspective. However, when filming from scenic pull-offs in National Parks, I realized that one direction was more scenic. My documentary film’s goal was to direct the audience's attention to that most picturesque location while also allowing it to explore the entire 360 field of view.

Composition Choices in You Are Here

To capture the park landscapes in 360 view, I used the VUZE XR and GoPro Max cameras. They are small, consumer-level VR360 cameras that allow for ease of use, including wearable devices affixed to a helmet or vehicle. To provide the viewer with an evocative visual experience, I manipulated the speed of clips to create a time-lapse effect in various scenes. I intentionally increased the apparent passage of time in landscape features like clouds, steam, and park visitors. Additionally, I edited clips to reflect the accurate progression of time, which creates a contrast to the time-lapse speed, and allows for the release of build-up tension that is created through the accentuation of time (Haywood, 2007).

After comparing the camera height used in the 360 natural history films *My Africa* and *Expedition Everest*, I decided that a camera should be placed at human eye-level to the surroundings. This mimics the feeling of being present at the physical location. However, I needed to increase the camera height above human eye-level at two park locations. In Yellowstone National Park, the necessity of my holding the camera tripod while filming thermal features was due to park regulations in fragile ecosystems. The camera height was above my head, so my body did not occlude the lenses. The second location where I raised the camera height above eye level was when I needed to ensure objects in close proximity did not block the distant landscape features. In Grand Teton National Park, I placed the camera close to the iconic T. A. Moulton Barn. To capture the barn and the Teton range behind it, I needed to extend the camera height above human eye level. This prevented the entirety of the barn from eclipsing the iconic mountains and represents a perspective that millions of Americans visit in person each year.

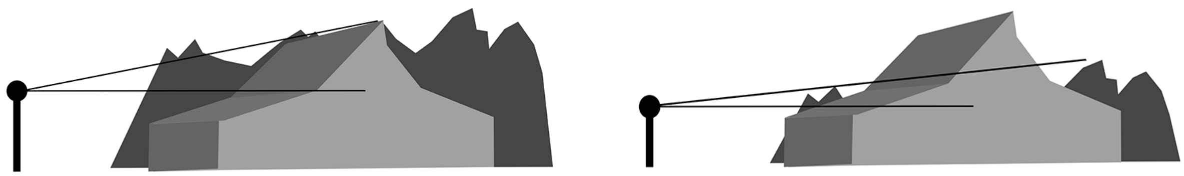

Figure 6. Camera Height Perspective. A camera height will determine the perspective of close objects in relation to distant objects. A taller height prevents the barn from completely occluding the distant mountains (left). A shorter camera height obscures the mountains and makes the barn appear larger (right).

In *You Are Here*, I chose to film most of my scenes from a stationary tripod, like in *My Africa* and *Expedition Everest*. In Grand Teton National Park and Yellowstone National Park, I wore the GoPro Max atop a helmet to emulate outdoor recreation opportunities available to park visitors. I like how the camera orientation perspective changes to unveil additional aspects of the scenery. This also helps focusing attention on the direction of travel, or objects moving along the same trajectory as the guide horse in the Tetons.

My use of shot duration diverged from the strategy used in *My Africa*. In *You Are Here*, I chose long takes that I felt allowed sufficient exploration of the landscape. However, I do not believe there is a single standard for how long the shot duration in 360 videos should be. This is because individual attention span and time perception vary, especially if it is the first time a person sees the film. I provided a framework to direct attention while allowing sufficient time to explore the entire field of view.

Using gaze, sound, motion, context, and perspective helps draw audience attention within a 360 field of view (Gödde et al., 2018). When Old Faithful is erupting, it’s unlikely witnesses are going to be looking in the opposite direction. In our spatial reality, audio clues help people detect the direction of events. 3D directional audio technology exists to pan specific sounds in 360/VR+ media to replicate sounds' directionality in real life. Because I did not have the equipment to film, edit, and playback 3D audio, I was limited to text on-screen and other compositional techniques to focus the viewer's attention. The choice to include text in the film is derived from the film's title–*You Are Here*. National Park workers create maps to identify where popular attractions are and place placards at pull-offs to let visitors know they have arrived. Text on screen is an added context which helps draw viewer focus through post-production text appearing on screen. A viewer can then associate the name of the 360 scenes to locations in the real world.

<u>360 Techniques For Directing Audience Attention</u>

In this section I describe, in detail, 360 composition techniques such as *equatorial horizon*, *polar exclusion*, *reference direction*, *and directional marker*, and how they work to direct audience attention. While these techniques exist in practice, they have not been defined before as unique filmic elements. I have defined these conventions from my observations of composition techniques in 360 films.

Equatorial Horizon –The horizon line of a 360 video should be as close as possible to the spherical equatorial line. Placing the horizon line at a height and angle separates the ground into the lower hemisphere and everything above the ground horizon in the upper hemisphere. It recreates a human's perspective of the landscape for viewers like if they were physically present at that location. Shifting this horizon level above or below the equatorial line on a globe can alter the perspective of a film. If the horizon above the equatorial line around the sphere, the video is closer to the "bug's-eye" perspective of a small point of view with imposing surrounding features. If the horizon is below the equator, the scenery is from a “bird's-eye” perspective, and now viewers will have to tilt their playback device down to see the ground.

Polar Exclusion –We should consider the 360 spherical video playback in the same way we think of the Earth's surface with latitude lines from the equator to the poles. The area above sixty-degrees latitude and negative sixty-degrees latitude is the “poles” of the globe. To see this area, the user must tilt their head/device sixty-degrees above or below the equatorial line of latitude. This deviation from a comfortable resting position at zero-degrees is unlikely to be sustained for prolonged periods, making the content that appears in the “poles” of the sphere less frequently observed by viewers. For this reason, my convention of Polar Exclusion states that the area at an angle between sixty-degrees and ninety-degrees from the equator should not have the most important objects or events in a 360 film. Conversely, we can think about the area outside of the poles for significant film action.

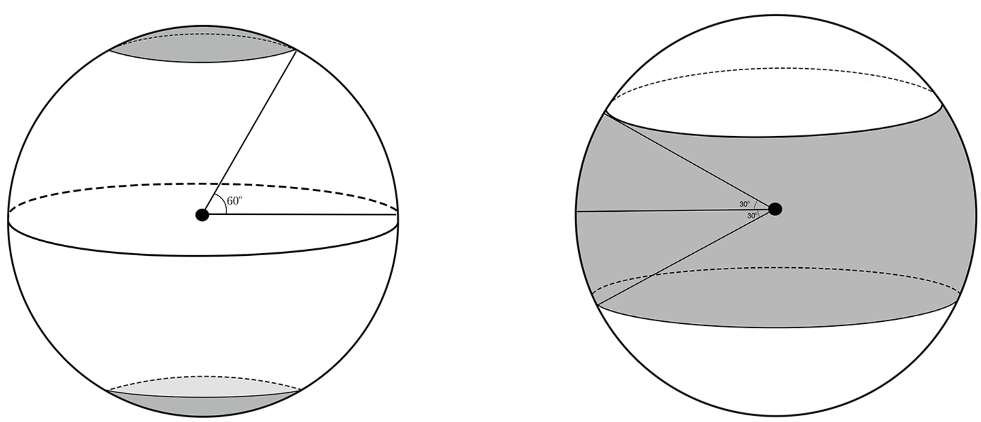

Figure 7. Sphere Zones. When the visual playback surface of the sphere is considered as angles in degrees from the center, the poles are sixty-degrees above and below the horizon line (left). Area of the sphere within thirty-degrees above and thirty-degrees below the horizon zero-degree angle (right).

30 Above 30 Below–The optimized area for action within the 360 sphere is the region thirty-degrees above and thirty-degrees below the equatorial zero-degree line. Most of what someone will see without having to tilt their head or playback device beyond the zero-degree equatorial line falls between the thirty-degree angle above or below the horizon. This region of the playback area is optimal for placing the faces of on-screen talent, as well as where prominent objects and important landscape features are best situated on screen. If an action occurs within this zone, the viewer can easily follow the direction of movement with simple pivoting motion compared to increasing or decreasing their playback device's vertical angle.

Singular Reference Direction–To keep users from missing out on the most crucial direction for action events or landmarks in each subsequent clip, I propose the idea of a reference direction for all clips. The location is determined in the equirectangular video as the "center" point of the video. While exploring in all directions around them, it is important for users to know that the filmmaker has chosen to place the most interesting focal point of a clip in the same 360-degree spot. By returning to the same compass direction, the viewer will not miss the important scene the filmmaker wanted them to see. The reference direction is kept in the same general location for all clips.

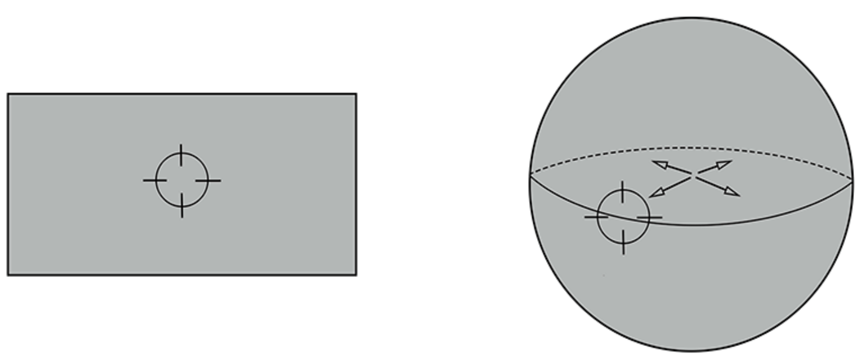

Figure 8. Reference Direction. Equirectangular video with reference direction (left). Spherical stitched playback of equirectangular video with singular reference direction (right).

Directional Marker – A physical or digital object is placed in a direction to indicate to the viewer where the most important subject matter is located. Directional markers can be signs or characters filmed in the 360 environment, as well as post-production elements like text. These markers should act as an item of interest or focal subject. Directional markers serve to direct audience attention by making the viewer linger on the location within the 360 view. If the marker is a person speaking, the accompanying audio is a clue for the viewer to survey the area until they locate the character. Pairing the directional marker with a reference direction increases the audience's attention in one area.

Upon completing my documentary film, I realized 360 media has an additional layer of visual-spatial perception called "haptic perception." Haptic perception is the sensory awareness of touch (Calbi et al., 2019). I have never experienced the urge to reach out and touch a TV or computer screen showing traditional flat formats of natural history film. However, while watching the film *You Are Here* with VR Goggles, I found myself reaching out to touch the mist coming off the Grand Prismatic Pool in Yellowstone. This heightened sensory awareness created in 360/VR+ formats is what I believe make viewers connect to 360 natural history films in a more experiential, sensorial way (Gillespie, 2020).

In *You Are Here,* I aimed to recreate the experience of being physically present at iconic National Park locations and used composition to help direct attention to specific locations in the 360 video. Additionally, I focused on the landscape features that moved and manipulated shot duration to accentuate that movement for an evocative experience. I used the 360 field of view to transport viewers into the National Parks landscape and developed new cinema compositions in 360.

CHAPTER EIGHT

THE FUTURE OF 360

Films like *My Africa*, *Expedition Everest*, and *You Are Here: National Parks in 360* are just some of the recent documentary films offered in the niche realm of 360 natural history filmmaking. The popularity of educational or adventure-based 360/VR+ media allows users to travel to distant places or settings that would be considered inaccessible, like the deep sea or outer space. With ever-increasing technological advancements, 360/VR+ media can become a viable option for routine virtual destination travel. Immersive media may also create a greater emotional connection between the viewers and the content in the film.

Researchers in Harvard's Innovation Lab saw increased engagement in participants who watched immersive media formats (Bertrand et al., 2018). Not only did they discover that viewers were learning while emotionally engaging with content, but they also found that spectators sustained these effects for extended periods afterwards (Rome, 2019). This can be summarized in the feeling of “being there,” profoundly impacting audiences (Jung, 2018). The increased sensory world of motion-responding head position tracking accompanied with audio and visual acuity opens up new opportunities for users (Chen & Fragomeni, 2018).

Currently, the highest demand for VR+ content includes applications for gaming and entertainment such as Beat Saber and Vader Immortal on Oculus, Google Earth VR, and YouTube VR content (Nicol, 2021; Best of Quest 2020: *A Look Back at the Year’s Top VR Games+ Apps, 2020*). An expansion of both technological affinity and VR+ services would be needed to transform this unique format into a ubiquitous service. Between 2014 and 2017, the number of VR+ users increased from 200,000 to 90 million (Vailshery, 2021). From 2018 and

2020, an estimated 57 million VR headsets were sold (Alsop, 2021). Currently, an estimated 52.1 million US citizens participate in virtual reality experiences each month, driving an expansion of media and new applications in VR+ (Alsop, 2021). However, the casual 360/VR+ user may only occasionally interact with the immersive realm of media. The average American has access to VR+ every day from smartphones offering AR services for accurately measuring room dimensions or playing games like Pokemon Go to IMAX planetarium shows and experiences offered at VR film festivals. Despite the advances in VR content, the current limitations in 360/VR+ are an obstacle to universal adoption of these new video formats.

It is unlikely that 360/VR+ will become as ubiquitous as the family room TV for entertainment purposes. This is due to price of equipment and complexity in operation. The technological requirements of the advanced VR+ user include both a headset and computing system, which can cost anywhere between a few hundred and a few thousand dollars, plus fees and subscriptions for App content (Papachristos, 2017). For a system with an upfront cost for use, VR+'s versatility and available content is still limited.

The operation and functionality of 360/VR+ playback devices is also limited. Headsets are designed to be operated by a single individual at a time. If multiple people want to view the same media or interact together within the virtual world, multiple VR+ devices are necessary. People can also suffer from vertigo or motion sickness while viewing content with VR goggles (Akizuki et al., 2004). Disabled individuals who could benefit from the escapism offered through 360 media are restricted by the range-of-motion required to interact with, wearing VR goggles, or holding smartphone playback devices (Giusto, 2020). The format of 360/VR+ media may not become ubiquitous in households across the world, but it has shaped the way we interact without the world and each other.

Regardless of the limitations of current 360 immersive media, the advancements in 360 technology shows potential for future innovation. New technologies of 360 camera have allowed filming in higher resolution and from different perspectives. UAV drones for 360 cinema are capturing the earth from a bird's-eye perspective (Zia et al., 2019). Stereoscopic 360 cameras film with multiple lenses to create a 3D playback experience in a 360 video. 360 cameras like the Live Planet 360 3D VR Camera advertises a 16-lens system that can livestream a 180 or 360 recording online (Lang, 2019). Even advancements in sound technology for 360 has created new immersive opportunities. An ambisonics microphone creates a 360 recording of the sound environment that allows sound to be directionally-linked to head movement in 360/VR+ content (RØDE Microphones, 2020). These advancements in 360 technology continue to push the boundaries of what is possible in 360 filmmaking.

Several media outlets have also embraced the 360/VR+ format. The New York Times online, National Geographic, and the BBC have all formed 360 journalism departments for the creation and display of immersive media. The New York Times began producing *The Daily 360*– short form 360 journalism content, which was uploaded online beginning in 2016. National Geographic's Grosvenor Hall Auditorium was outfitted with 450 Oculus Go VR headsets in 2018 in what became Washington D.C.'s first VR theater experience ("Tech With A Purpose", 2019). In 2020, the BBC's 360 natural history endeavor Micro Monsters partnered with Alchemy Immersive to produce an immersive 8K natural history series from a bug's-eye perspective for Oculus users ("Micro Monsters," 2020).

Despite the adoption of 360 by major media companies, the future of 360 is still uncertain. The investment in 360/VR+ content has declined significantly since it hit the market in 2016 (Lee, 2019). Google Cardboard devices were discontinued in 2021 and National Geographic's VR theater has remained closed due to the ongoing COVID-19 pandemic (Wilde, 2021). While the pandemic has halted group VR experiences, it has been a driving force in the sale of VR+ equipment with more VR goggles sold in 2020 (Statista, 2021). During the pandemic, consumers want content they can access from the comforts and safety of home. 360 virtual shows and 360 virtual vacations might become the future of immersive entertainment in a post-COVID world, where travel and physical presence continues to be more dangerous and have social stigmas. Regardless of whether 360 and VR+ are niche formats, their unique attributes are unparalleled in today's video-driven world.

REFERENCES CITED

Agtzidis, I., Startsev, M., & Dorr, M. (Eds.). (2019). *360-degree Video Gaze Behaviour*. ACM. https://doi.org/10.1145/3343031.3350947

Aitamurto, T., Zhou, S., Sakshuwong, S., Saldivar, J., Sadeghi, Y., & Tran, A. (2018). Sense of Presence, Attitude Change, Perspective-Taking and Usability in First-Person Split-Sphere 360° Video. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 2–10. https://doi.org/10.1145/3173574.3174119

Alsop, T. (2021, March 22). Virtual Reality (VR) - statistics & facts. Statista. https://www.statista.com/topics/2532/virtual-reality-vr/

Akizuki, H., Uno, A., Arai, K., Morioka, S., Ohyama, S., Nishiike, S., Tamura, K., & Takeda, N. (2005). Effects of immersion in virtual reality on postural control. *Neuroscience Letters*, *379*(1), 23–26. https://doi.org/10.1016/j.neulet.2004.12.041

Bertrand, P., Guegan, J., Robieux, L., McCall, C. A., & Zenasni, F. (2018). Learning Empathy Through Virtual Reality: Multiple Strategies for Training Empathy-Related Abilities Using Body Ownership Illusions in Embodied Virtual Reality. Frontiers in Robotics and AI, 5, 1–26. https://doi.org/10.3389/frobt.2018.00026

Bichlmeier, C., Wimmer, F., Heining, S.M., Navab, N.: Contextual anatomic mimesis hybrid in-situ visualization method for improving multisensory depth perception in medical augmented reality. In: 2007 6th IEEE and ACM International Symposium on Mixed and Augmented Reality, pp. 1–10 (2007).

Blum J.R., Greencorn D.G., Cooperstock J.R. (2013) Smartphone Sensor Reliability for Augmented Reality Applications. In: Zheng K., Li M., Jiang H. (eds) Mobile and Ubiquitous Systems: Computing, Networking, and Services. MobiQuitous 2012. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 120. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-40238-8_11

Boas, Y. (2013). Overview of virtual reality technologies. In *Interactive Multimedia Conference* (Vol. 2013).

Bousé, D. (2000). *Wildlife Films* (Illustrated ed.). University of Pennsylvania Press.

Calbi, M., Aldouby, H., Gersht, O., Langiulli, N., Gallese, V., & Umiltà, M. A. (2019). Haptic Aesthetics and Bodily Properties of Ori Gersht's Digital Art: A Behavioral and Eye-Tracking Study. *Frontiers in Psychology*, *10*, 1–4. https://doi.org/10.3389/fpsyg.2019.02520

Carvalho, P. (2018). Following the White Rabbit: The Virtual Reality for Games. *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry*, 172–183. https://doi.org/10.1007/978-3-319-91584-5_14

Chen, J., & Fragomeni, G. (2018). Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry 10th International Conference, VAMR 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part II.

Conservation International. (2018, April 30). My Africa | Official 360 Film [HD] | Conservation International [Video]. YouTube. https://www.youtube.com/watch?v=119f0l7sqwg

Corbillon, X., Simon, G., Devlic, A., & Chakareski, J. (2017). Viewport-adaptive navigable 360-degree video delivery. *2017 IEEE International Conference on Communications (ICC)*, 1–6. https://doi.org/10.1109/icc.2017.7996611

D'Amico, L. (2013). *Ecopornography and the Commodification of Extinction: The Rhetoric of Natural History Filmmaking, 1895-present*. (Publication No. 1303650665) [Doctoral dissertation, Texas A&M University]. ProQuest Dissertations Publishing.

Ellis, J., & McLane, B. (2005). A new history of documentary film. New York: Continuum.

Fernández-Bellon, D., & Kane, A. (2019). Natural history films raise species awareness—A big data approach. *Conservation Letters*, *13*(1), 1–4. https://doi.org/10.1111/conl.12678

Gillespie, C. (2019). Virtual Humanity—Access, Empathy and Objectivity in VR Film Making. *Global Society*, *34*(2), 145–162. https://doi.org/10.1080/13600826.2019.1656173

Giusto, G. (2020). *From Script to Screen: Connecting Creatives in 360° Virtual Reality Filmmaking*. (Publication No. 9798662437371) [Master's Thesis, Drexel University]. ProQuest Dissertations Publishing.

Gödde, M., Gabler, F., Siegmund, D., & Braun, A. (2018). Cinematic Narration in VR – Rethinking Film Conventions for 360 Degrees. *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry*, 184–201. https://doi.org/10.1007/978-3-319-91584-5_15

Haywood, K. (2007). *Beyond words : The use of the non-verbal genre in natural history filmmaking* (No. 1290682). Montana State University - Bozeman. https://scholarworks.montana.edu/xmlui/handle/1/1449

Hovanec, C. (2019). Another Nature Speaks to the Camera: Natural History and Film Theory. *Modernism/Modernity*, *26*(2), 243–265. https://doi.org/10.1353/mod.2019.0030

Jung, S. (2018). The Message Effect of Augmented Health Messages on Body. *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry*, 86–93. https://doi.org/10.1007/978-3-319-91584-5_7

Kasic, K. (2007). *Perspective in wildlife films*. (Publication No. 175281307) [Master's thesis, Montana State University]. Thesis and Dissertations at Montana State University (MSU).

Lai, J. S., Peng, Y. C., Chang, M. J., & Huang, J. Y. (2020). Panoramic Mapping with Information Technologies for Supporting Engineering Education: A Preliminary Exploration. *ISPRS International Journal of Geo-Information*, *9*(11), 689. https://doi.org/10.3390/ijgi9110689

Lang, B. (2019, January 23). *Live Planet Launches All-in-one System for 360 3D Livestreaming*. Road to VR. https://www.roadtovr.com/live-planet-launches-all-in-one-system-for-360-3d-video-capture-distribution/

Lee, W. (2019, January 15). *VR gets reality check with significant decline in investment*. PHSY.ORG. https://phys.org/news/2019-01-vr-reality-significant-decline-investment.html

Louson, E. (2018). Taking Spectacle Seriously: Wildlife Film and the Legacy of Natural History Display. *Science in Context*, *31*(1), 15–38. https://doi.org/10.1017/s0269889718000030

MacIsaac, D. (Ed.). (2015). Google Cardboard: A virtual reality headset for $10? *The Physics Teacher*, *53*(2), 125. https://doi.org/10.1119/1.4905824

Micro Monsters: mighty next-gen immersive content in stunning 8K. (2020, November 18). Foundry. https://www.foundry.com/insights/vr-ar-mr/micro-monsters

Modrak, R., & Anthes, B. (2010). *Reframing Photography: Theory and Practice* (1st ed.). Routledge.

National Geographic. (2020a, June 22). Expedition Everest: The Mission - 360 | National Geographic. YouTube. https://www.youtube.com/watch?v=KM6HWp_ik2c&t=86s

National Geographic. (2020b, June 29). Expedition Everest: The Science - 360 | National Geographic. YouTube. https://www.youtube.com/watch?v=twVdBzQM-gc

National Parks Adventure (2016). *About The Film*. PDF file. https://nationalparksadventure.com/wp-content/uploads/2016/01/NPA-Production-Notes-Final.pdf

Nicol, W. (2021, March 31). *The best VR apps for 2021*. Digital Trends. https://www.digitaltrends.com/virtual-reality/best-virtual-reality-apps/

Papachristos, N., Vrellis, I., & Mikropoulos, T. (Eds.). (2017). *A Comparison between Oculus Rift and a Low-Cost Smartphone VR Headset: Immersive User Experience and Learning*. IEEE. https://doi.org/10.1109/icalt.2017.145

Patterson, K. (2017). Genome gazing: A 360° stereoscopic animation for Google cardboard. In *2017 IEEE Virtual Reality (VR)* (pp. 439-439). IEEE Computer Society.

Rabiger, M. (2015). Directing the Documentary. Burlington, Massachusetts: Focal Press.

RØDE Microphones. (2020, April 21). *The Beginner's Guide To Ambisonics*. https://www.rode.com/blog/all/what-is-ambisonics

Rothe, S., Sarakiosis, V., & Hussmann, H. (Eds.). (2019). *Where to Place the Camera*. ACM. https://doi.org/10.1145/3359996.3364798

Rome, R. (2019). *Narrative Virtual Reality Filmmaking: A Communication Conundrum*. (Publication No. 1392119510) [Doctoral dissertation, Regent University]. ProQuest Dissertations Publishing.

Scott, K. D. (2003). Popularizing Science and Nature Programming: The Role of "Spectacle" in Contemporary Wildlife Documentary. *Journal of Popular Film and Television*, *31*(1), 29–35. https://doi.org/10.1080/01956050309602866

Somaiya, R. (2015, October 20). *The Times Partners With Google on Virtual Reality Project*. The New York Times. https://www.nytimes.com/2015/10/21/business/media/the-times-partners-with-google-on-virtual-reality-project.html

Statista. (2021, January 14). *Impact of COVID-19 on the YoY growth rate of AR/VR headset shipments Q1 & Q2 2020*. https://www.statista.com/statistics/1104978/covid-19-impact-on-ar-vr-headset-shipment-growth-rate/

Suzuki, K., Nakamura, F., Otsuka, J., Masai, K., Itoh, Y., Sugiura, Y., & Sugimoto, M. (2017). Recognition and mapping of facial expressions to avatar by embedded photo reflective sensors in head mounted display. *2017 IEEE Virtual Reality (VR)*, 177–185. https://doi.org/10.1109/vr.2017.7892245

Tech with a Purpose: National Geographic Museum Introduces First Virtual Reality Theater Experience in Washington, D.C.: World-renowned National Geographic photographers virtually transport visitors to Earth's most extraordinary places with SPACES. (2019, August 21). National Geographic Society Newsroom. https://blog.nationalgeographic.org/2018/10/03/tech-with-a-purpose-national-geographic-museum-introduces-first-virtual-reality-theater-experience-in-washington-d-c/

Vailshery, L. S. (2021, January 22). Number of virtual reality users forecast worldwide 2014–2018. Statista. https://www.statista.com/statistics/426469/active-virtual-reality-users-worldwide/

Vox. (2017, February 20). How the BBC makes Planet Earth look like a Hollywood movie [Video]. YouTube. https://www.youtube.com/watch?v=qAOKOJhzYXk

Ward, P. (2003). Picture Composition for Film and Television. Boston, Massachusetts: Focal Press.

Wilde, D. (2021, March 3). *Google Store stops selling Cardboard VR headsets*. 9to5Google. https://9to5google.com/2021/03/03/google-store-stops-selling-cardboard-vr-headsets/

Willcox, J. (2021, January 15). The TVs coming from LG, Samsung, Sony, Tcl, and others in 2021. Retrieved March 15, 2021, from https://www.consumerreports.org/tvs/what-to-expect-from-tvs-in-2021

Wilk, Elizabeth Clare. (2019). *Deeper Connections through Interactivity in the Virtual Space*. [Master's thesis, Montana State University]. Thesis and Dissertations at Montana State University (MSU).

Yalin Xiong, & Turkowski, K. (1997). Creating image-based VR using a self-calibrating fisheye lens. Proceedings of IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 237-243.

Yu-Chuan, S., & Grauman, K. (Eds.). (2017). *Learning spherical convolution for fast features from 360° imagery: Vol. Proceedings of the 31st International Conference on Neural Information Processing Systems (NIPS'17)*. https://doi.org/10.5555/3294771.3294822

Zia, O., Kim, J. H., Han, K., & Lee, J. W. (2019). 360° Panorama Generation using Drone Mounted Fisheye Cameras. *2019 IEEE International Conference on Consumer Electronics (ICCE)*, 1–5. https://doi.org/10.1109/icce.2019.8661954