EFFECTS OF CHARACTER GUIDE IN IMMERSIVE VIRTUAL REALITY STORIES

A Thesis

by

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ABSTRACT

Bringing cinematic experiences from traditional film screens into Virtual Reality (VR) has become an increasingly popular form of entertainment in recent years. VR provides viewers unprecedented film experience that allows them to freely explore around the environment and even interact with virtual props and characters. For the audience, this kind of experience raises their sense of presence in a different world, and may even stimulate their full immersion in story scenarios. However, different from traditional film-making, where the audience is completely passive in following along director's decisions of storytelling, more freedom in VR might cause viewers to get lost on halfway watching a series of events that build up a story. Therefore, striking a balance between user interaction and narrative progression is a big challenge for filmmakers.

To assist in organizing the research space, we presented a media review and the resulting framework to characterize the primary differences among different variations of film, media, games, and VR storytelling. The evaluation in particular provided us with knowledge that were closely associated with story-progression strategies and gaze redirection methods for interactive content in the commercial domain.

Following the existing VR storytelling framework, we then approached the problem of guiding the audience through the major events of a story by introducing a virtual character as a travel companion who provides assistance in directing the viewer's focus to the target scenes. The presented research explored a new technique that allowed a separate virtual character to be overlaid on top of an existing 360-degree video such that the added character react based on the head-tracking data to help indicate to the viewer the core focal content of the story. The motivation behind this research is to assist directors in using a virtual guiding character to increase the effectiveness of VR storytelling, assuring that viewers fully understand the story through completing a sequence of events, and possibly realize a rich literary experience.

To assess the effectiveness of this technique, we performed a controlled experiment by applying the method in three immersive narrative experiences, each with a control condition that was free

from guidance. The experiment compared three variations of the character guide: 1) no guide; 2) a guide with an art style similar to the style of the video design; and 3) a character guide with a dissimilar style. All participants viewed the narrative experiences to test whether a similar art style led to better gaze behaviors that had higher likelihood of falling on the intended focus regions of the 360-degree range of the Virtual Environment (VE).

By the end of the experiment, we concluded that adding a virtual character that was independent from the narrative had limited effects on users' gaze performances when watching an interactive story in VR. Furthermore, the implemented character's art style made very few difference to users' gaze performance as well as their level of viewing satisfaction. The primary reason could be due to limitation of the implementation design. Besides this, the guiding body language designed for an animal character caused certain confusion for numerous participants viewing the stories. In the end, the character guide approaches still provided insights for future directors and designers into how to draw the viewers' attention to a target point within a narrative VE, including what can work well and what should be avoided.

DEDICATION

To my family and friends.

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1. INTRODUCTION

1.1 Introduction

Virtual Reality (VR) has become a growing entertainment medium. As defined by Jerald [1], VR is "a digital environment that enables users to experience and interact as if that environment were real." It mainly incorporates visual and auditory, and sometimes even other types of sensory feedback such as haptic. Because of this, VR can provide the audiences unprecedented film experience that raises their sense of presence in a different world. By encouraging the audiences to freely explore an immersive environment and even interact with virtual props and characters, VR has great potential to induce full immersion into the story scenarios. In recent years, several innovative techniques have been designed and developed to experiment with storytelling in virtual spaces and many cutting-edge VR stories have been showcased in numerous film festivals [2], such as Sundance, SXSW, Tribeca and Cannes. The major production company Walt Disney Animation Studios has also debuted their first VR animation *Cycles* [3] at SIGGRAPH this year.

One of the biggest challenges directors face when telling a story through VR is determining how to best guide viewers through important events of a narrative without hindering their freedom to explore and discover the virtual world. In the traditional film industry [4], there already exists an established film language that directors can employ to present specific portions of a narrative to the audiences in exactly the manner and order they desire. For instance, directors have long relied-on camera shots and post-editing to create cuts between different scenes in order to convey the important messages of a story. In this case, the directors have absolute control over the storytelling process. Meanwhile, the role of the audience is passive; they can only wait and receive a selective amount of information within a set frame of the camera.

On the other hand, Steuer [5] identifies real-time interaction as one of the main variable characteristics of VR, which indicates the audience's role transition from being absolutely passive to more active. Unlike telling a story in traditional media, in VR, viewers are encouraged to alter their senses in relation to the virtual environment (VE), including their points of view, location and so on, solely by turning their heads or moving around in whatever manner they choose to.

However, allowing the audience more freedom to explore and interact within a narrative scenario might lead them to getting lost following a series of events that build up a story. Hence, VR filmmakers must formulate ways to maintain relative control over story presentation in order to ensure that the audience does not miss any important information about the story. For example, in order to guide viewers through a complete narrative experience in VR, it is crucial for content creators to conditionally add guiding assistance as redirecting cues to shift the user's attention toward the relevant events and objects within the environment [6].

1.2 Motivation and Objective

The motivation behind this research is to study the discipline in depth and determine ways to assist directors in creating better story experiences in VR. The research objective of this thesis is to construct a framework by summarizing and characterizing what has been achieved so far in order to overcome this challenge in both the academic and commercial domains. Furthermore, we also wanted to contribute new knowledge by examining the effects of a virtual character guide as a potential gaze redirecting technique for immersive VR stories. The research is important because the future creators can follow the resulting framework and refer the experiment outcomes to develop better VR narrative experiences that are easier to follow and more enjoyable to watch.

To assist in organizing the research space and to discover the most-used storytelling strategies and attention guidance techniques across the variety of interactive media, we have presented a Media Review of more than 80 different interactive works.

Thereafter, we have proposed a new gaze redirection technique using a virtual character guide. The method overlays a guiding character on top of an existing 360-degree video and has the added character react based on the user's head-tracking data in order to help direct the user toward the focal content of the story. To assess the effectiveness of this technique, we conducted an experiment that followed a three-way within-subjects design. We identified three groupings based on pairing VR videos and different character guide conditions. The groupings were considered an additional between-subjects factor in the experimental design. We prepared three different 360-degree animated videos and set them up in Unity [7]. Next, we created three distinct virtual character guides, where each character has a corresponding art style to a specific video being presented. We implemented the use of these character guides as the gaze redirecting technique within the structure of each video. The purpose was to have the user's gaze follow a designed guiding character towards a target area within the implemented VE. We especially focused on evaluating whether a character guide's art style would affect the users' gaze behavior and influence their enjoyment of a story experience. Thus, the experiment compared three variations of the character guide: 1) no guide, 2) a guide with a matching art style to the video design, and 3) a guide with a non-matching art style. We then asked 30 participants to watch these stories in VR using head mounted displays (HMDs). The participants were divided into three groups to vary the combinations of specific video-character pairing. Each group determined which guidance condition the participants experienced per movie, but all participants experienced all three movies and all three variations of the character-guiding factor.

By the end of this study, we concluded how to best draw viewers' attention to a target point with the help of a designed character guide, such as what works well and what should be avoided. We also determined whether the implementation of a character guide affects the user's entertainment level of a VR story. Moreover, we acquired knowledge regarding the types of guiding movements performed by the character guide that were the most effective in VR story experiences.

2. LITERATURE REVIEW AND RELATED WORK

2.1 Storytelling Trend with Technology

Immersion and interactivity, as argued by Ryan [8], have been the main motivating forces behind some of the major paradigm shifts in the history of narrative and human culture. Throughout history, storytelling has been developed in a variety of forms in terms of the different media that carry them; these forms range from oral expression, theatrical performances, and prints to movies. Consider the history of cinema for example. The major trend of cinematic storytelling has been and still is closely related to producing a vivid-sensation experience by immersing the audience as much as possible into a story scenario. Cinema was first invented during the 1890's in the form of black-and-white moving images through photographing motion [4]. The earliest films, despite a complete absence of sound and a plain display of simple monochrome images, attracted many audiences at that time because the early scenics that were shot "gave viewers glimpses of faraway lands" that they were not physically at [4].

Figure 2.1: A screen-shot of one of the earliest films, *Rough Sea at Dover* (Birt Acres, 1895) showed the scenic of large breaking waves crashing against a seawall.

In the 1920's, sound cinema came into existence. After years of practices and improvement, filmmakers and technology workers successfully managed to add and mix separate soundtracks combining original music, sound effects, and synchronizing voices [4] as a supplement to the motion pictures. The invention of sound films greatly stimulated viewers' auditory senses along with their visual senses and, therefore, further raised their sense of presence in a world that they were not physically present in. Subsequently, with the development of technology, not only were color films introduced but also, directors were able to shoot their movies using high-end digital video cameras, creating and showing high-definition (HD) films with sharper resolution to the audience rather than standard-definition (SD) films. Nowadays, producing 3D stereoscopic films to enhance the illusion of depth perception is a common practice in the movie industry through which viewers are able to obtain a more realistic visual experience and, thus, feel more immersed in the stories being shown on screen. In conclusion, an important trend in storytelling, despite the types of medium the creators use, is to raise audiences' sensory satisfaction and level of immersion associated with the story world.

Figure 2.2: A screen-shot of *Avatar* (James Cameron, 2009), the first feature-length stereoscopic film that showed an entire 3D, photo-realistic world.

2.2 VR as a Narrative Medium

The emergence of Virtual Reality (VR), as Steuer reasoned [5], fulfilled the desire to bring greater sensory depth to traditional media content by immersing viewers in a 360-degree visual environment. Jerald [1], defined virtual reality as "computer-generated digital environment that can be experienced and interacted with as if that environment were real." He further described VR to have the ability to "provide our minds with direct access to digital media in a way that seemingly has no limits" [1]. For this reason, VR is perceived and studied by numerous people as a medium that possesses substantial potential for telling a story through its powerful sensory input.

Aylet and Louchart [9] maintained that VR should be considered as a specific narrative medium along other traditional narrative forms such as theater, literature, and cinema. However, they reasoned that VR narrative designers must be aware of the participants' active role within the Virtual Environments (VEs) as opposed to their purely passive role in cases of experiencing a story through watching a film or reading a book. They argued that the traditional methods of presenting a story cannot be directly applied to a VR narrative environment. Some form of manipulation must be taken into consideration so as to ensure that the viewers will not remain passive.

Similarly, Clarke and Mitchell [10] attempted to review certain methods used in traditional film-making in order to determine whether they can be applied and situated in the construction of a VR narrative. The methods that were examined include continuity of time, space, and action as well as character interaction. They suggested that VR content creators abandon the traditional reliance on the continuity of time, space, and action to focus mainly on character interaction.

Various researchers and artists began experimenting with the use of VR as a storytelling medium over two decades ago. For instance, Pausch et al. [11], at Disney Imagineering, summarized a few effective strategies for creating an engaging VR experience from the *Aladdin Ride* they designed back in 1996. They found it beneficial to provide the audience with a background story and assign them a concrete goal to accomplish in the VE. More recently, Google Spotlight's *DUET* [12] put together a two-line story experience based on the main characters, a boy and a girl. This design allowed the audience to follow whichever story-line they preferred and watch the story develop along that line. Creators also implemented a butterfly to lead the viewers' attention to the story scene if they were to ever get lost in the environment. Oculus Story Studio's *Henry* [13] presented an eye-contact experience between the viewers and the main character, Henry the hedgehog, creating a more intimate connection between the audience and the story. Penrose Studio's *Allumette* [14] followed more of a long-established filmmaking approach, which involved several camera cuts to transfer audiences from one space and time to another, etc.

2.3 Gaze Redirection in VR

Many researchers have conducted specific studies that aim at exploring and assessing the effects of various gaze-redirecting techniques in VR. Some of them focused on designing perceptual properties that will make visual objects stand out from their surroundings. These visual salience cues include, but are not limited to, luminance contrast, edge or line orientation, color, and motion. For instance, Hillaire et al. [15] constructed and evaluated models of dynamic blur that combine depth of field and peripheral blur effects to direct user navigation in the VE. Smith and McNamara [16] developed a dynamic real-time color effect stimulus to redirect the user's gaze toward points of interest. Specifically, whenever the viewer looked away from the target points, the designed stimulus would make the image appear more yellow-green, which decreases the viewers' enjoyment level and motivates them to look at certain points. Adenuga [17] put forward the adapting of certain cinematic and theatrical lighting techniques to attract the viewer's attention in virtual scenarios. Danieau et al. [18] suggested driving the user's gaze smoothly toward a point of interest by applying fade to black and desaturation visual effects outside of the area of interest.

Some researchers focused on manipulating the camera to change the viewer's gaze relative to a target area within the VE. Bolte and Lappe [19] proposed rotating the camera during a rapid movement of the eye between fixation points (saccade) to a non-perceivable degree. Sargunam et al. [20] investigated the use of amplified head rotation as a redirection technique, in which they produce a rotation angle by multiplying the tracked physical head orientation and an amplification factor. This allows the viewing of a 360-degree virtual world by physically turning the head through a comfortable range. They also evaluated guided rotation as another redirection technique, which realigns a users' head orientations as they virtually translate through the VE. Stebbins and Ragan [21] explored a scene rotation-based method for redirecting a viewer's gaze in a 360-degree movie. In particular, the scene rotation with a calculated rotation angle is triggered if the user has looked at an sufficiently extreme angle (angle threshold) for more than a particular length of time (rotation delay). Brown et al. [22] studied direct scene transitions and forced camera rotation for a multi-user VR narrative experience. Specifically, the technique of direct scene transition makes the camera fade out and then fade back in with the event in the center of a viewer's field of vision. The technique of forced camera rotation makes the user camera rotate, independently of the user, to face the event taking place.

Besides these, others used the approach of employing animated three-dimensional figures as guiding indicators. Brown et al. [22] implemented a firefly as a visual distractor in the multi-user VR narrative experience. The firefly would drift into a user's field of view and flied off screen in the general direction of the active story event. The firefly would remain in the user's field of view until he/she witnesses the story event taking place. If the user failed to follow the firefly, it would re-enter the user's line of sight and repeat its action until it is noticed. Pausch et al. [11] built virtual characters to point at or even move toward the target scene when directing user's attention. Similarly, Wernert and Hanson [23] introduced personal "guides" in a designer-assisted system to help the user to focus on the target subject areas in the navigation space. We chose to expand on this technique following the Media Review to better express the story.

2.4 Interaction with a Virtual Character

The primary aim of building a virtual character in Human Computer Interaction is to induce greater understanding by enhancing the efficiency of the information being exchanged. Moreover, implementing a companion type of virtual character is expected to create emotional bonding between the user and the character, which can lead to a higher enjoyment level.

Many researchers have studied the effects of human-to-virtual-character interaction as an interface design approach in real-time systems. These virtual characters can be designed and appear in the form of either a human or an animal. The effects are different, but each form has its own benefits and convenience.

On one hand, according to Cassell [24], the advantage of designing virtual humans as interfaces is that the communication information involving gestures or facial expressions is "transparent" to the user. If designed and implemented properly, a virtual human agent will largely increase communication efficiency. Since a virtual human agent is designed after a human, the user has a natural ability to recognize and respond quickly to its messages as in face-to-face communications. In addition, based on a research by Takeuchi et al. [25], users can accomplish tasks smoothly and effectively when the attitude and behavior of a virtual agent resembles theirs. This study supported that Human-Computer interaction possesses the same social dynamics as Human-Human interaction. In other words, people's experience with real social interaction will enrich their experience with human-computer interaction. As a consequence, it is likely that the users may receive intensive information from a personified virtual character.

On the other hand, same as humans, animals also manifest social qualities. As Wang et al. [26] pointed out, a virtual companion will establish a certain emotional connection with its user and may take the form of a pet. In this case, mutual dependencies and closeness are built between a virtual companion and the user. Last, a past research conducted by Hofmann et al. [27] approved that "the presence of a virtual companion (compared to being alone)" led to a higher level of cheerfulness for individuals watching a comedy film. As a result, applying a virtual character properly in an interactive scenario, which functions as both a guide and a companion, may reduce the users' feeling of loneliness and enhance their level of enjoyment.

3. MEDIA REVIEW

3.1 Media Review

To better organize the research space and situating our work in the context of existing VR storytelling framework, we reviewed over 80 different real-time rendered interactive content on the current market. The resulting framework characterizes the primary differences among different variations of film, media, games, and VR experiences.

We began by examining a variety of animated stories that involved the technology of VR and Mobile VR. Generally, we considered these works to have a first-person experience, and that the content being rendered and showcased within the 360-degree environment is based on the user's head-tracking data. In addition, the visual fidelity of these works ranged from a lower degree that concerned with 2D stylized animations, and a medium degree that included works of 3D stylized designs to very few higher fidelity works associated with realistic CG rendering. Moreover, we carefully evaluated and recorded the character interaction levels of these works. In particular, if the audience's choice could change a character's behaving decisions and its long-term role development within an experience, we considered the interaction level to be high. If the audience did not influence a character's growth, but could have conversations to exchange certain information, then the level of interaction would be medium. Last, if a character can only acknowledge the existence of the audience via subtle signals such as eye contact, then we decided that the character interaction was low.

Apart from these, we also included narrative content with the highest visual fidelity possible, which is live-action short films that were specifically designed to be experienced in VR. However, these works typically have lower interaction fidelity that comprised of neither solid given tasks, nor object manipulation throughout the experience. They also barely required user navigation such as the movement of either physical or virtual position. In this case, the only attention engaging strategy that the directors chose to rely on was the story itself, especially consider that the story was presented in VR and was free from the help of camera composition or post-editing techniques.

Following that, we extended our review scope to include other types of interactive technologies, such as works in Augmented Reality (AR) and computer/video games. AR and VR are similar to certain extent in terms of using space effectively to immerse the users into a series of event scenes, while computer/video games are a well-developed interactive field where various interface design techniques have been created and successfully applied. Specially, it is important that we establish an in-depth understanding of "gamified" storytelling, which usually involves concrete goals expected to be achieved by the users along their experience of unfolding a story.

Finally, we browsed through more VR experiences that focused on demonstrating the interactivity of an unreal world. Typically, the visual fidelity for these experiences was low, as the creators' design expressions were usually creative-driven and were mostly abstract. These works contain limited narrative elements, but offer the audience more freedom to wander around and explore within the VE.

After an informal analysis of all these works, we classified them into four major categories based on the design objectives of the content or methods applied during presentation:

1. Interactive Experience
2. Game
3. Interactive Film (Not-animated)
4. Interactive Film (Animated)

One of our research goals was to study how former creators struck a balance between story presentation and user interaction. Therefore, we evaluated and summarized the common qualities from each category, including the implementation of narrative, design of guidance techniques, and level of character interaction. We especially focused on studying the most-used storytelling strategies and gaze redirection techniques for the works under "Animated Interactive Film" with supporting literature.

3.1.1 Categories and Characteristics

3.1.1.1 Interactive Experience

The “Interactive Experience” category comprises of the works that do not involve narratives or game tasks. These works are the most abstract out of all those reviewed, as there is often a lack of clear storylines or specific goals expected to be accomplished. For content designers, the most important thing is to demonstrate to the audience that VR can be a powerful tool that offers significant visual, auditory, and even haptic stimulus. Due to its design objectives, there are usually no gaze redirection techniques created and implemented in these experiences. Depending on the content, the level of character interaction in these experiences is mostly low, or there is no character interaction at all.

Table 3.1: Evaluation results under the category of “Interactive Experience.”

Interactive Experience				
Name	**Medium**	**Narrative**	**Gaze Redirection**	**Character Interaction**
THEBLU: Encounter	VR	No	No	Low
Longing for Wilderness	VR	No	No	None
The Pull	VR	No	Yes	None
Way to Go	VR	No	No	Low
In the Eyes of the Animal	VR	No	No	None
Sightline: The Chair	VR	No	No	None
Blocked In	VR	No	No	None
Der Grosse Gottlieb	VR	No	No	None
The Marchland	VR	No	No	None
The Night Cafe	VR	No	No	Low
The Dreams of Dali	VR	No	No	Low
Under Neon Lights	VR	No	Yes	None
Kinoscope	VR	No	No	None
The Evolution of Verse	VR	No	No	Medium
Transition	VR	No	No	Low

3.1.1.2 Game

The "Game" group refers to the works that involve a set of specific tasks expected to be accomplished throughout the experience. Oftentimes, there is a clear narrative involved in most games. However, the primary design objective for a gaming experience is not to tell a story; rather, the stories are generally introduced as a background context to assist users in understanding and completing their game tasks. The most common gaze redirection techniques designed for games are usually quite obvious, such as a GUI element of a text box that displays particular instructions or a symbol such as an arrow. Occasionally, the redirection technique can even pause the progression of the game without affecting the user's gaming experience in a negative way. Last, the level of character interaction for this category is typically medium to high.

Table 3.2: Evaluation results under the category of "Game."

Game				
Name	**Medium**	**Narrative**	**Gaze Redirection**	**Character Interaction**
League of Legends	PC game	Yes	No	High
Minecraft	PC game	Yes	No	High
World of Warcraft	PC game	Yes	No	High
Grand Theft Auto	PC game	Yes	No	High
Dota	PC game	Yes	No	High
Diablo	PC game	Yes	No	High
The Legend of Zelda	PC game	Yes	No	High
Halo	PC game	Yes	No	High
Call of Duty	PC game	Yes	No	High
Final Fantasy	PC game	Yes	No	High
Pokemon GO	AR	No	No	High
Ingress	AR	Yes	No	High
The Machines	AR	Yes	No	High
Digg's Nightcrawler	AR	Yes	No	High
Fragments	AR	Yes	No	High
Lucid Trips	VR	No	No	Medium
Irrational Exuberance	VR	No	No	Medium
Memories of a No Man's Land	VR	No	No	Medium

Continuation of Table 3.2				
Name	**Medium**	**Narrative**	**Gaze Redirection**	**Character Interaction**
Cosmic Trip	VR	No	No	Medium
Robinson: The Journey	VR	Yes	No	High
Firebird: La Peri	VR	No	No	Medium
Back to Dinosaur Island	VR	Yes	Yes	High
Old Friend	VR	No	No	Low

3.1.1.3 Interactive Film (Not animated)

"Interactive Film (Not animated)" are categorized by a documentary film type of experience. There is often a clear narrative involved, and users do not need to complete specific tasks other than watching the story. Many experiences under this category feature either places that most audience cannot go, such as the outer space or deep in the ocean, or stories that present the aftermath of a significant disaster, such as an earthquake or military attack. Consider the primary design objective for this kind of content as recording and displaying something the way it is; there is also no gaze redirection technique being implemented. The level of user interaction included is also quite limited, entailing that the users cannot necessarily affect a virtual character's action, but can occasionally feel the eye contact.

Table 3.3: Evaluation results under the category of "Interactive Film (Not-animated)."

Interactive Film (Not Animated)				
Name	**Medium**	**Narrative**	**Gaze Redirection**	**Character Interaction**
Arctic 360	VR	No	No	Medium
Women in Military Service	VR	Yes	No	Low
Gift of Mobility: Zambia	VR	Yes	No	None
Welcome to Aleppo	VR	Yes	No	None
The Nepal Quake Project	VR	Yes	No	None
Witness 360: 7/7	VR	Yes	No	Low
Reframe Iran	VR	Yes	No	Low
Journey to the Edge of Space	VR	No	Yes	None

Continuation of Table 3.3				
Name	**Medium**	**Narrative**	**Gaze Redirection**	**Interaction**
The Invisible Man	VR	Yes	No	None

3.1.1.4 Interactive Film (Animated)

"Interactive Film (Animated)" is categorized by animation shorts that are interactive. The biggest difference between the works falling under this category and those from the aforementioned category is that interactive animations usually include the design and implementation of various gaze redirection techniques. This is done not only because the stories and styles for most animated films are creative, which makes it reasonable and less abrupt to incorporate additional guiding elements, but also, it's easier to do so with the help of CG.

Table 3.4: Evaluation results under the category of "Interactive Film (Animated)."

Interactive Film (Animated)				
Name	**Medium**	**Narrative**	**Gaze Redirection**	**Character Interaction**
Drawing Room	VR	Yes	Yes	None
Notes on Blindness: Into Darkness	VR	Yes	No	Medium
Pearl	VR	Yes	No	None
Rain or Shine	VR	Yes	Yes	None
Buggy Night	VR	No	Yes	Medium
On Ice	VR	Yes	Yes	None
Special Delivery	VR	Yes	Yes	None
Windy Day	VR	Yes	Yes	None
DUET	VR	Yes	Yes	None
Back to the Moon	VR	Yes	Yes	Low
Sonaria	VR	No	Yes	Low
Piggy	VR	Yes	Yes	Medium
Son of Jaguar	VR	Yes	Yes	None
HELP	VR	Yes	Yes	Low
Lost	VR	Yes	Yes	Low
Henry	VR	Yes	Yes	Low
Dear Angelica	VR	Yes	Yes	None
INVASION!	VR	Yes	Yes	Low

Continuation of Table 3.4				
Name	**Medium**	**Narrative**	**Gaze Redirection**	**Character Interaction**
ASTEROIDS!	VR	Yes	Yes	Low
Crow: The Legend	VR	Yes	Yes	Low
JACK	VR	Yes	Yes	None
The Rose and I	VR	Yes	No	None
Allumette	VR	Yes	Yes	None
Arden's Wake: The Prologue	VR	Yes	No	None
Arden's Wake: Tide's Fall	VR	Yes	No	None
COLOSSE	VR	Yes	No	None
The Fantastic Flying Books of Mr. Morris Lessmore	VR	Yes	No	None
The Numberlys	VR	Yes	No	Low
The Last Mountain	VR	Yes	No	Low

3.2 Story Progression

Besides the design objectives and common interactive traits based on the different media categories presented above, we also summarized some prevalent strategies associated with story progression in VR from this media review. We particularly focused on evaluating the experiences under the "Interactive Film (Animated)" category, where numerous creative and effective story-progression strategies were established. We also reviewed more literature works to support these findings.

Story progression in VR usually involves conditionally adding in constraints or creating guiding assistance. According to a research conducted by Nielsen et al. [6], there are three prevalent approaches that content creators like to apply in furthering the story progression in VR. First, the story automatically pauses before the user notices a target event, and whether the user has perceived that event is deduced based on his/her head or gaze direction. The story will continue only after the user turns to a certain angle and the important events and objects in the scene have been presumed as "observed". Second, certain narrative systems would dynamically present events and objects within the user's field of view. Third, the filmmaker will use various directing cues (such as the mise-en-scene and sound) to transfer the user's attention toward relevant events or objects within the environment.

In addition to this, below we have provided in-depth explanations of what we have summarized from the media review and certain approaches proved and supported by Nielsen's [6] statements. Whereas, the other approaches that we found based on the media evaluation have been presented as follows:

3.2.1 Area Restriction

One of the most common techniques content creators use in VR storytelling is limiting the action area that is directly related to the target event within the field of view. This means that within a 360-degree environment, about two thirds of the areas are filled with minor actions or even no action. Therefore, even though the user has the freedom to look and wander around, he/she will eventually stop exploring and simply focus on what is actually moving in the environment. *Rain or Shine* [28] by Nexus Interactive is a good example of applying this technique in some of the scenes to further the story.

3.2.2 Time Extension

Another general technique involves extending the interval between each crucial plot to ensure that users have enough reaction time. This strategy is similar to what Nielsen et al. [6] summarized as "story halted before the user sees an important scene." Besides that, this approach also includes situations wherein the story continues no matter where the viewer is looking but in a very slow pace, increasing the likelihood of the viewers catching up and following the narrative. The purpose of this strategy is to ensure that the user has identified each target event along the story-line in order to allow them to fully understand the intended meaning of the story. For instance, *Colosse* [29] is a VR animation that exploits this strategy, as one of its main characters moves at a very slow pace. Further in our study, we will be testing our designed gaze redirecting technique in the story of *Colosse* [29] on top of its existing story progression strategy.

3.2.3 Distractors

The last technique that assist the progression of a story involves visual or audio cues as attention guidance tools. A good example of the distractor technique is Crytek's *Back to Dinasour Island* VR Demo [30]. In this demo, creators successfully attract the viewer's gaze by utilizing a dragonfly distractor that keeps bumping into the corner of the camera along with a constant wing-flapping sound, which generates both visual and audio stimulus to grab the viewer's attention. With the help of this dragonfly, there is a lower chance that viewers would miss the next important scene. Although applying visual distractors is a more popular approach in most existing VR storytelling experiences, exploiting stereo disparity to attract the user's attention can also be quite effective. Auditory distractors take the form of sounds in the environment relatively close to the target event occurring. This technique assumes that the users will hear the distractors and turn to face them. For example, *Sonaria* [31] by Google Spotlight Stories demonstrates how music and sound could be designed for a 360-degree environment to assist storytelling and achieve a vivid narrative experience in VR. Both visual and audio distractor techniques allow the storytellers to suggest an action to the audience without forcing it on them.

3.3 Review Conclusion

From the Media Review, we gave a short statement of the medium types and the most common values associated with the inclusion of clear narratives and gaze redirection techniques between the four major content categories. We also examined different levels of character interaction among these reviewed groups, as displayed below in Table 3.5. In particular, we were able to present a solid framework by summarizing and analyzing the prevalent methods that directors applied to maintain a relative control when presenting a story in VR. The established structure provided us with extensive knowledge that were closely related to story-progression strategies and gaze redirection approaches for interactive content in the commercial domain. The evaluation was important because the future directors can refer the resulting framework to design and develop VR narrative works for better viewing experiences.

	Medium	**Narrative**	**Gaze-Redirection**	**Character Interaction**
Interactive Experience	VR	No	No	None
Game	Mixed	Yes	No	High
Interactive Film (Not-animated)	VR	Yes	No	None
Interactive Film (Animated)	VR	Yes	Yes	None/Low

Table 3.5: A brief comparison of the main differences among the four major content categories.

However, we found specifically that among various guidance techniques in immersive VR stories, limited examples exist regarding the application of virtual characters. What is more, the level of character interaction in works that involved narratives is typically lower or non-existent. Subsequently, we situated our proposed design of applying virtual character guides as a potential gaze redirection approach in VR stories within the existing framework. In the following chapter, we present the conducted study testing and evaluating the effects of this proposed technique.

4. USER STUDY OF CHARACTER GUIDES

4.1 Character Guidance

As discussed at the end of the Media Review chapter, there exist limited examples that use a virtual character to direct the audience's attention in the current VR storytelling framework.

It might be useful to consider using virtual characters as a gaze redirection approach when presenting a story in VR because previous research has proved that employing animated figures as guiding indicators were helpful in facilitating the user to focus on target subject areas and navigate within a VE [11] [23]. Moreover, other studies found that a personified virtual agent may strengthen communication efficiency, since users tended to recognize and respond quicker to signals based on common sense in social interaction [24]. In addition, users are more likely to accomplish tasks smoothly and effectively when the behavior of a virtual agent is similar to theirs [25]. Therefore, as a part of the presented research, we chose to study the effects of character guides in directing the viewers' gaze in VR.

However, as different stories have diverse designs regarding visual styles and creative outcomes, it would be difficult to custom-create a new character guide for each specific experience. Hence, we proposed the method of overlaying a separate virtual character on top of an existing 360-degree video and allowing the added character to react based on the head-tracking data in order to guide the viewer to the focal content of the story. The benefit of exploring this method was that it would be more useful and convenient if a working character guide could be added to other existing applications as a part of the immersive interface. For this reason, it is important that we examine whether it works, how well it works, and other associated design factors that could influence the qualifications of this approach.

Particularly, there is an issue regarding the freedom of creators and the potential of adding a character guide to an existing story. In other words, if adding an external character guide that was not created specifically to match its background, it might not fit with the story's visual design, and users might find it distracting for their viewing experience. Consequently, we were required to consider whether the art style of a character guide should match the presented story and thus, we tested whether a similar art style can lead to better eye-gaze performances and viewing experience.

4.2 Research Goals

We expect the guiding character technique to facilitate users' gaze performances in terms of capturing important events of a VR story in a designed order and potentially increase users' entertainment levels of interactive story experiences. The motivation behind this study is to assist future directors in developing better VR narrative experiences that are easier to follow and more enjoyable to watch. To assess the effectiveness of this technique, we conducted a three-way within-subjects experiment, in which the participant's gaze was expected to follow a designed guiding character towards a target area within the implemented VE. Our primary focus was on evaluating whether a character guide's art style would affect the users' gaze behavior and influence their enjoyment of a story experience.

4.3 Research Questions

The specific research questions (RQ) expected to be answered through this study are listed as follows:

RQ 1: Is a character guide useful in redirecting viewers' gaze to a target field of view (FoV) within a VR story?

RQ 2: Does the character's art style matter in terms of guiding?

RQ 3: How does a character guide affect user levels of enjoyment of a VR story?

RQ 4: What types of nonverbal character behavior are most effective for guiding?

4.4 Experimental Design

For this research, we proposed to introduce a designed guiding character to lead our users through a sequence of essential story events in VR and ensure that they do not miss any of them. To simplify the experimental procedure, we identified three groupings of the three VR videos and character guide conditions [1]. The experiment followed a three-way within-subjects design to assess the effects of an added character guide and the style of an added character guide matching the video's style. The groupings can be considered an additional between-subjects factor in the experimental design. The experiment compared three conditions:

4.4.1 Guidance Conditions

1. Story experience without a guiding character (control condition)

2. Story experience with a guiding character that has a non-matching art style

3. Story experience with a guiding character that has a matching art style

Other than the art style, we also intended to determine the types of nonverbal behavior that were most effective in terms of attention-grabbing as well as redirecting in an interactive VR story experience. Based on the different characters, we have designed and implemented several guided body languages, such as pointing towards a specific direction, turning towards a specific direction, facing the user, and jumping up and down.

To provide variability in testing, the study used multiple immersive 360-degree videos. We prepared three different 360-degree animated videos and set them up in Unity [7] as the background. All three stories were presented as first-person experiences, and the camera used to display the VEs was placed at the user's eye level. We created three groups of pairings with stories in order to study how these factors affected the users' viewing behavior of an interactive VR story. The pairing between the primary independent variable (character guide style) and the videos was varied between subjects to provide variability in different combinations of character guide style and story design.

To study different character designs and matching the stories, we created three distinct virtual character guides, where each character has a corresponding art style to the video being displayed. For each VR experience, we chose two character guides out of three and implemented them as the

[1] See **"Experimental Design Groupings"** in Appendix for detailed pairings and combinations of video and character conditions.

gaze redirecting technique within the framework. We showed only one character guide at a time and hid the other when playing each VR experience to the audience. The implemented guiding characters were not a part of the storyline, nor did they affect the development of the story. The only function they served in the narrative scenario was to attract the viewer's attention to a target region within the environment where an important event was taking place. In other words, the user's gaze was expected to follow the character guide toward the goal area within the implemented VEs.

4.4.2 Hypotheses

1. In an interactive VR story experience without a character guide, if a virtual character guide is implemented, the user's gaze is more likely to fall on the target areas throughout the experience, and users are more likely to follow up with important story events.

2. In an interactive VR story experience with a character guide with a non-matching art style, if a virtual character guide that has a matching art style is implemented, the user's gaze is more likely to fall in the target areas throughout the experience, and users are more likely to follow up with important story events.

3. In an interactive VR story experience with no character guide, if a virtual character guide is implemented, the user's level of enjoyment of the story will be enhanced.

4.4.3 Character Creation and Implementation

Before the experiment, we first prepared three different 360-degree animated videos as our VR story experiences [2]. Each video had a distinct art style and story development:

Video 1: *Rain or Shine* [28] [3]

Video 2: *Colosse* [29] [4]

[2] See **"Video Setup in Unity"** in Appendix for detailed procedures of setting up 360-degree videos in Unity with its panoramic video feature.

[3] *Adapted with permission from *Rain or Shine* by Felix Massie, 2016, Google Spotlight Stories, USA. Copyright [2018] by Google Spotlight Stories.

[4] *Adapted with permission from *Colosse* by Nicholas Pittom, 2016, Fire Panda Ltd., UK. Copyright [2018] by Fire Panda Ltd.

Video 3: *INVASION!* [32] [5]

After setting up the videos in Unity [7], we created three different virtual character guides, with each character having a corresponding art style to the video being shown:

1. A girl character with an art style corresponding to *Rain or Shine* [28] - Figure 4.1
2. A fox character with an art style corresponding to *Colosse* [29] - Figure 4.2
3. A rabbit character with an art style corresponding to *INVASION!* [32] - Figure 4.3

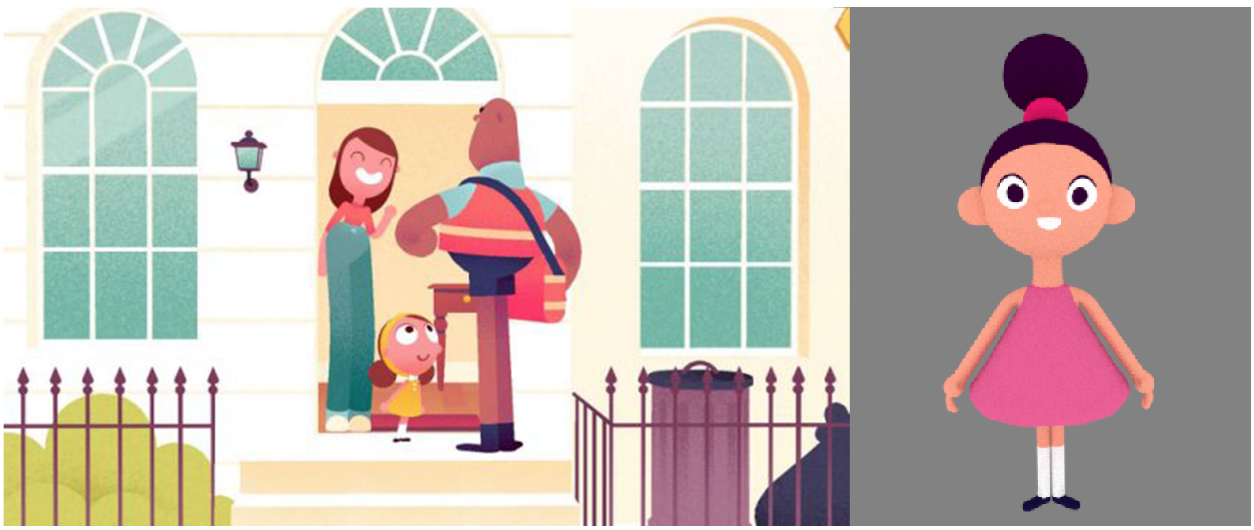

Figure 4.1: A screen-shot of *Rain or Shine* (Massie, 2016) compared with a render image of the girl.

The 3D characters were modeled, rigged, and animated in Autodesk Maya [33]. The polygon meshes of the models were unfolded into 2D planes for creating textures. The textures were pained in Adobe Photoshop [34] and then projected back onto the 3D meshes in Maya. We animated each character with several different body movements associated with the different objectives. The major animation we created for each character included the following:

1. Girl:

[5]*Adapted with permission from *INVASION!* by Eric Darnell and Ethan Hawke, 2016, Baobab Studios Inc., USA. Copyright [2018] by Baobab Studios Inc.

Figure 4.2: A screen-shot of *Colosse* (Pittom, 2016) compared with a render image of the fox.

Figure 4.3: A screen-shot of *INVASION!* (Darnell, 2016) compared with a render image of the rabbit.

   (a) Point left or right - for gaze redirecting along the horizontal direction

   (b) Point up or down - for gaze redirecting along the vertical direction

   (c) Jump up and wave - for grabbing attention

2. Fox:

(a) Turn to left or right - for gaze redirecting along the horizontal direction

(b) Jump up or dig down - for gaze redirecting along the vertical direction

(c) Bark - for grabbing attention

3. Rabbit:

(a) Turn to left or right - for gaze redirecting along the horizontal direction

(b) Look up or look down - for gaze redirecting along the vertical direction

(c) Jump - for grabbing attention

After the animation, we exported each body movement out as separate .fbx files to be imported into the Unity package. By setting up an Animation Controller for each character in Unity 3D, we were able to trigger a specific action of the characters under a certain condition. For example, consider a situation wherein a user is looking at the wrong region within the VE along the horizontal direction when an important story event is occurring to his left side that is out of his FoV. The girl guide will first jump up and wave to let the user know that he is looking in the wrong direction before pointing to the left to redirect his gaze back to the target event. The fox guide will first turn to face the left direction straightaway and then begin barking to draw the user's attention in case he does not notice the redirecting action of turning. The rabbit guide's action is primarily the same as the girl guide, in that it would first jump up as a sign to catch the user's attention and then turn its body to face left for the purpose of redirecting user's gaze. Despite the same goal of gaze redirecting, the action of turning is more implicit in terms of conveying the message of "look that way" as compared to pointing, which is a universal gesture of instructing somebody to pay attention to a specific direction. Through implementing and testing these different body movements in different orders, we learned what worked well and what did not.

4.4.4 Study Methods and Materials

As mentioned earlier, we determined three groupings to vary the combinations of specific character-video pairing. Per VR video, there was a sequence of target scenes, wherein each target scene displayed a focal event along the story development time-line within the 360-degree VE. These scenes were determined based on several factors:

1. The main character of the story is performing a major action;

2. The secondary character(s) is performing a major action, and the main character's action has become secondary;

3. The secondary object(s) is introduced in the story, and the main character's action has become secondary; and

4. The event in one scene must relate to the event occurring in the following scene. For example, if a user missed Scene 1, there is a chance that he would feel confused when watching Scene 2.

As Figure 4.4 illustrated, every target scene has a goal gaze direction and a valid FoV within the story's VE. The FoV range was set to 120 degrees along the horizontal direction and 100 degrees along the vertical direction. We expected our viewers to pay attention to these events while watching the stories.

Figure 4.5 below shows an example of the user's head orientation (gaze direction) from a top-down view in relation to a target scene during a specific time period along the story time-line of *Rain or Shine* [28]. We also included a screen-shot of the corresponding target scene [6].

For each VR experience, we chose two character guides out of three and implemented them as the gaze redirecting technique within the framework. In particular, each story included one character with a non-matching art style, and one character with a matching art style. We displayed only one character guide at a time and hid the other when playing the VR experience for the audience. In addition, every story was also presented in its original version without any character guides. We took a screen-shot per condition from *Rain or Shine* [28] presented during our test as examples in the figures presented below, where the highlighted area on each figure is the target scene. Figure 4.6 shows an example of the control condition with no guiding character; Figure 4.7 shows a non-matching guiding character; and Figure 4.8 shows a matching guiding character.

[6] See **"Target Scenes and Expected FoVs"** in Appendix for detailed illustrations of all movies' target scenes with corresponding time periods.

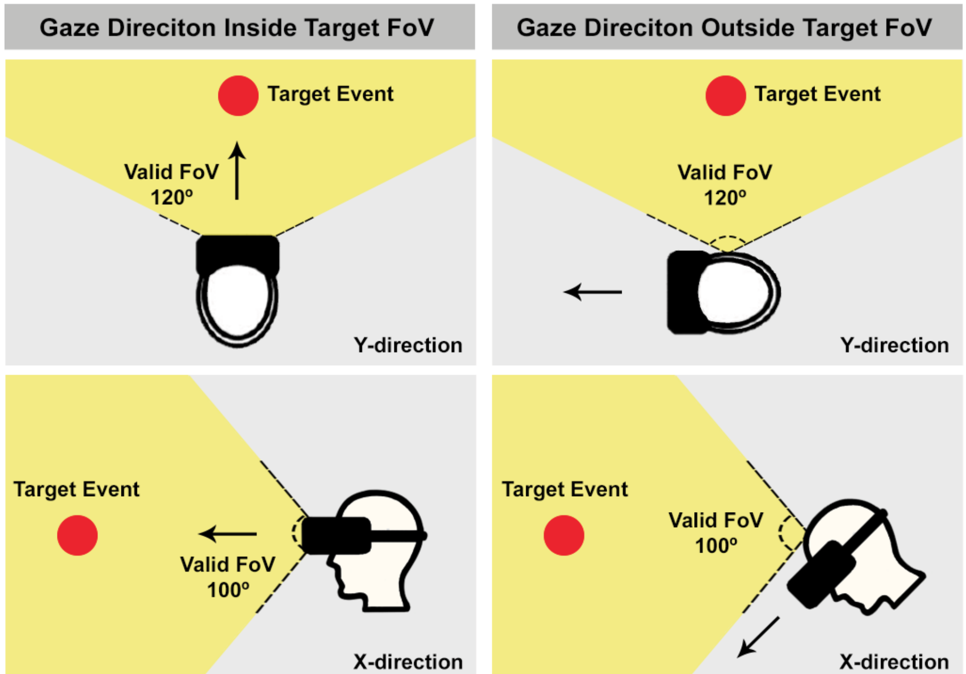

Figure 4.4: The user's head orientation (gaze direction) in relation to a target event and its valid FoV along the horizontal and vertical directions.

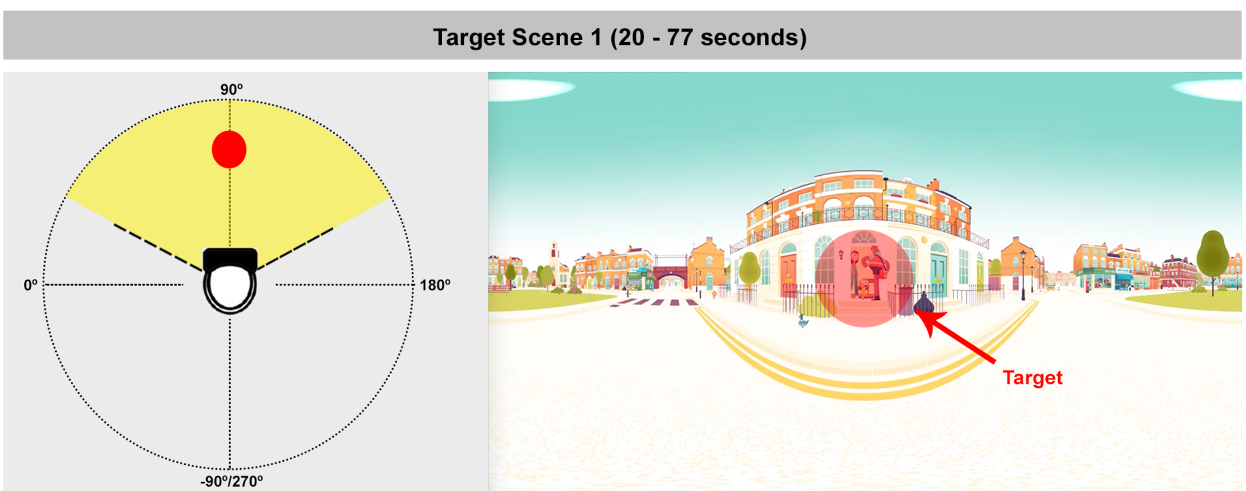

Figure 4.5: The user's head orientation relative to a target event and its valid FoV, and a screen-shot of the event occurring.

We divided our study participants into three identified groups at random. Participants were assigned to one group that indicated which character condition they experienced for each movie,

Figure 4.6: Condition 1 - No character guide is shown.

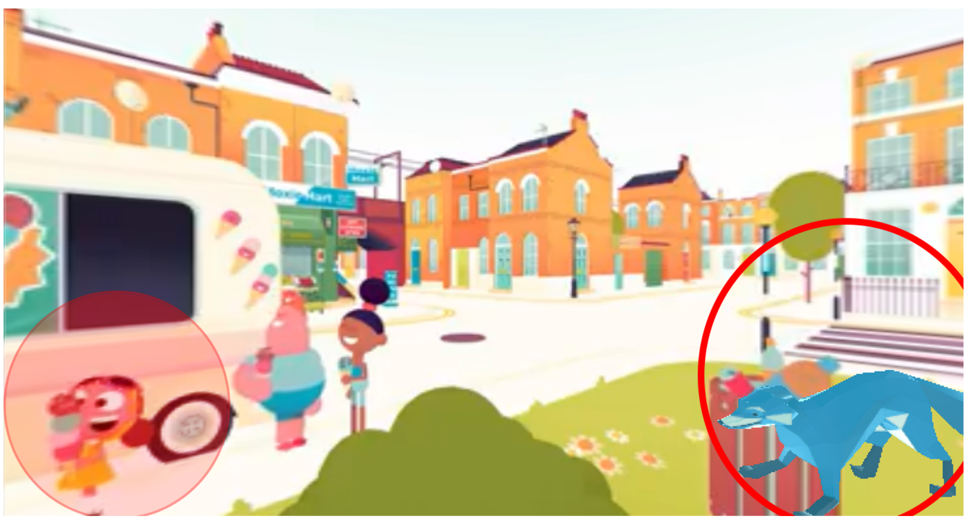

Figure 4.7: Condition 2 - The red circle shows the non-matching character guide.

but all participants experienced all three movies and all three variations of the character-design factor [7].

All participants were seated on a swivel office chair during our experiment. The users' interactions with the VR experiences only involved head and body rotations. We used HMDs to track their head orientation, which helped us determine where their gazes fell throughout the experiences. We

[7]**"Table 5.1"** in Appendix shows specific groupings of videos and character guides used in the experiment.

Figure 4.8: Condition 3 - The red circle shows the matching character guide.

recorded and saved quantitative data every 0.2 seconds during the experiment. The data was saved to a .csv file for each participant for every story that was being watched. This data included the following:

1. Run-time of each VR experience
2. Target scene IDs for each VR experience
3. User's head orientation (gaze direction) along X-axis and Y-axis throughout each VR experience
4. Guiding character's animation being triggered

Moreover, we also collected qualitative data during each study session via observing user reactions and performances. Particularly, we gathered a post-study questionnaire and conducted an in-depth structured interview that aimed to determine each participant's experience in detail after the study. Through this process, we received both positive and negative responses. The qualitative data provided us with valuable information regarding the users' subjective thoughts of a character guide in immersive VR stories. We also learned from their suggestions about how we may improve this gaze redirecting technique for a better viewing experience in the future.

4.5 Experimental Procedure

We conducted an IRB-approved study (IRB Number: IRB2018-0159D). Each experimental session lasted for approximately 60 minutes. Each study participant was presented with a paper printout with informed consent information. We explained the consent information and asked the participant to read the form. The participant was informed of the risks, such as minor motion sickness or eye strain, associated with computer and game technology and was told that they could stop participating at any time during the experiment. The participant was then asked to provide signed consent before continuing with the study to acknowledge that we could record data relating to their gaze performance and general thoughts. All data and findings were anonymized.

We also asked each participant to complete a background questionnaire via a web form to collect information such as age, gender, education, occupation, average weekly computer usage, and the participant's experience with video games and VR. We then explained the study task to our participants, which required them to wear a VR headset and that they were free to look around in order to become familiar with the environment that they would be in. Then, the participants were asked to watch three short animated 360-degree videos in VR. All of the videos contained non-disturbing images and were safe to view. Each video lasted for approximately 4-5 minutes. We gave each participant the option to take at least one break every 15 minutes to reduce the chances of feeling sick if they wished to do so. During the video presentation, we tracked the direction and duration of the participant's gaze.

After completing a VR experience with each guidance technique, we asked the participant to complete a questionnaire to collect information such as preferred technique, ease of use, natural level, and sense of immersion. Last, we conducted a semi-structured interview [8]. The purpose of this interview was to gather detailed information about the participants' thoughts regarding their experience of interactive VR stories with a character guide. Interview responses together with responses given to the previously submitted questionnaires provided us with valuable information

[8] See **"Interview Question Examples"** in Appendix for questions we included during the semi-structured interview.

about the effects of exploiting a character guide as a possible gaze redirecting technique in VR storytelling.

4.6 Participants

There were a total of 30 participants from the Texas A&M University who participated in our study. All of them participated in the experiment voluntarily. Based on the background survey conducted prior the study, twenty-one out of thirty (70%) were male and nine (30%) were female. Six (20%) of them were between the age of 18 and 20, twenty-one (70%) were in their 20's, two (7%)were in their 30's, and one (3%) was in his late 50's. Twenty-six (87%) were students, with majors ranging from Visualization, Computer Science and Engineering, Aerospace Engineering, and Construction Science to Biology, etc. Four (13%) were working in the education or nursing field. Twenty-nine (96%) participants had prior experience in playing video games or had watched interactive animated films before. Thirteen (43%) spent more than two hours engaging in the above mentioned activities on a weekly basis. On the other hand, twenty-five (83%) had experience with VR before, yet twenty-three of them (92%) spent less than two hours per week engaging in VR activities. All participants were divided randomly into three groups to vary the combinations of specific character-video pairing [9].

4.7 Results

For every VR video, we made two charts (one for Y-axis and one for X-axis) that illustrate how each user's gazes moved during the experience under all three conditions. For example, Figure 4.9 and Figure 4.10 below displayed users' gaze data along the Y-axis and X-axis while watching *Rain or Shine* [28]. There are 30 lines in total for each chart. Specifically, the 10 lines in red represent the gaze data of the participants that watched the story without a character guide; the second set of 10 lines in blue represent the gaze data of participants that watched the story with a non-matching character guide; and the last set of 10 lines in green represent the gaze data of participants that watched the story with a matching character guide. The charts also display a target FoV region

[9]See **"Experimental Design Groupings"** in Appendix.

in yellow for each target scene throughout the video. This helped us better visualize whether the users' gazes were inside or outside of a target FoV in a particular scene.

Figure 4.9 and Figure 4.10 displayed users' gaze data along Y-axis and X-axis while watching *Rain or Shine* [28].

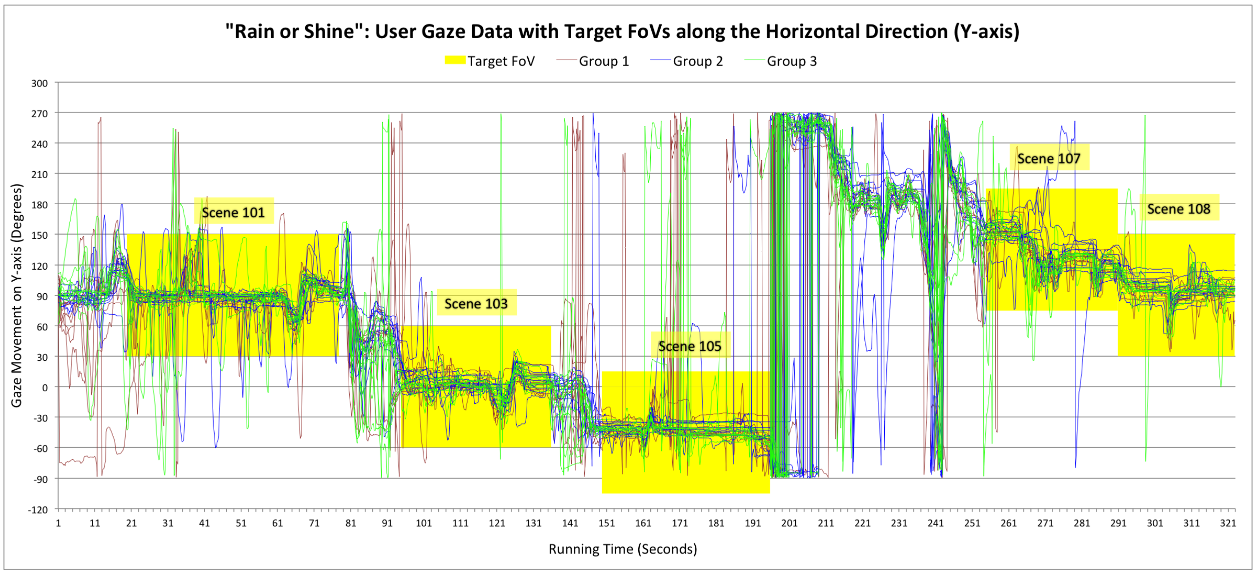

Figure 4.9: Gaze Data for *Rain or Shine* (Massie, 2016) along Y-axis.

Figure 4.11 and Figure 4.12 displayed users' gaze data along Y-axis and X-axis while watching *Colosse* [29].

Figure 4.13 and Figure 4.14 displayed users' gaze data along Y-axis and X-axis while watching *INVASION!* [32].

As mentioned earlier in this chapter, each target scene showed a certain focal event along the story-line within the 360-degree VE and were determined by several factors. We set the FoV for each target scene as 120 degrees along the horizontal axis and 100 degrees along the vertical axis, which created a valid region. If the user's head orientation data (which also represents his gaze direction) fell in this region during the time period that the corresponding events were occurring, then we assumed that he/she was looking in the target FoV for that particular scene. On the

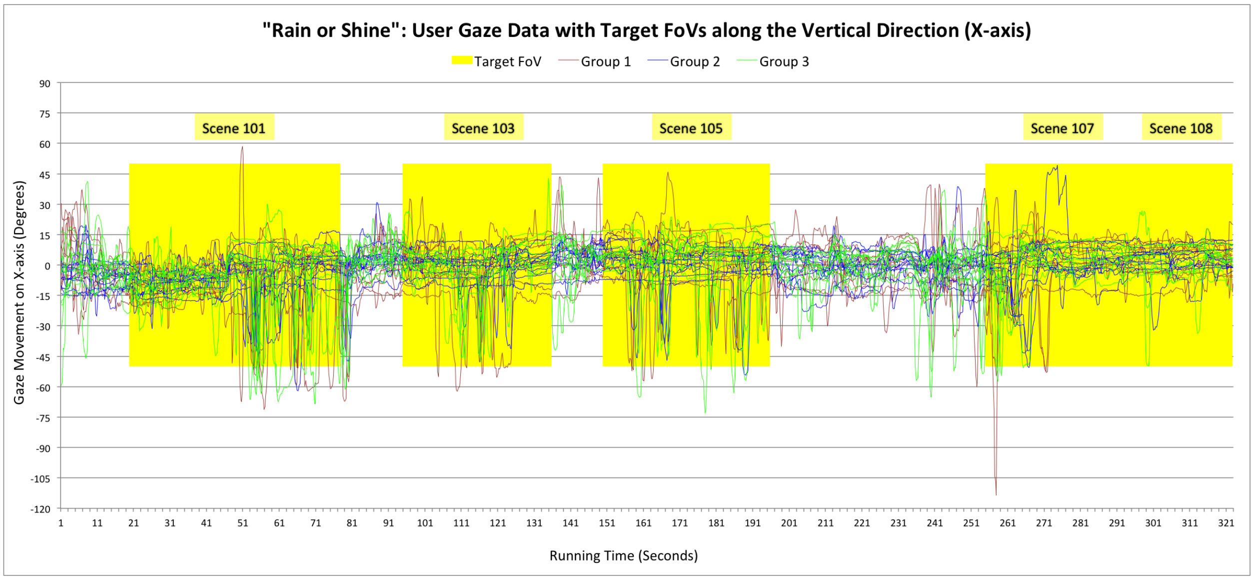

Figure 4.10: Gaze Data for *Rain or Shine* (Massie, 2016) along X-axis.

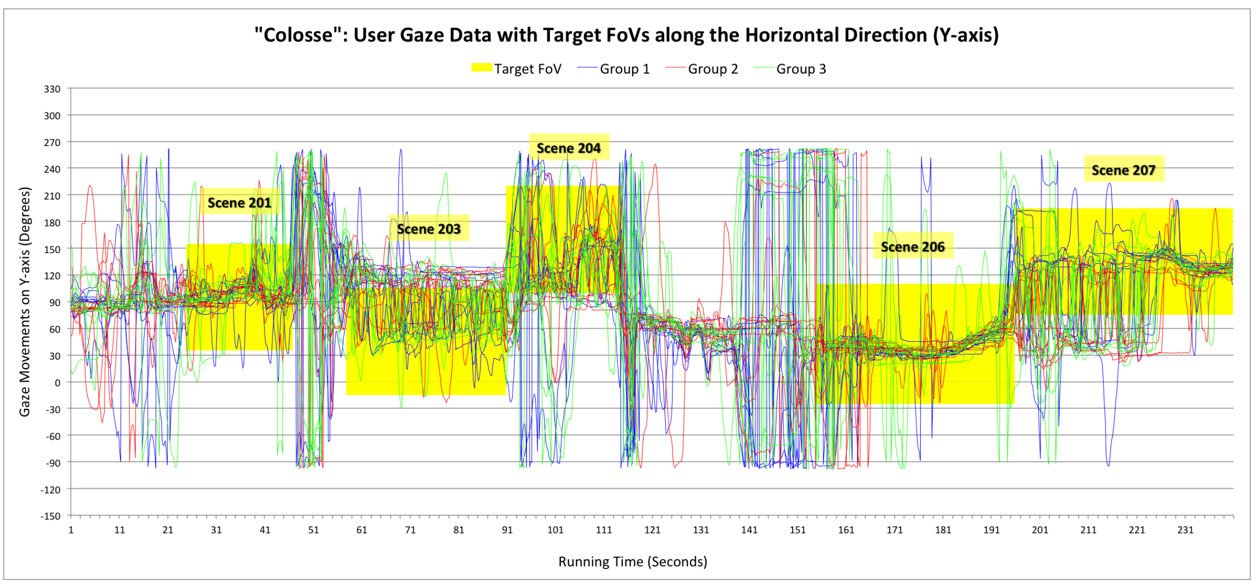

Figure 4.11: Gaze Data for *Colosse* (Pittom, 2016) along Y-axis.

contrary, if the user's gaze direction did not fall in the region during that specific time period, we assumed that he was looking outside that target FoV.

Moreover, since the users' gaze data was tracked every 0.2 seconds, we counted the total number of gazes that were recorded during the time period of a particular target scene. We also counted

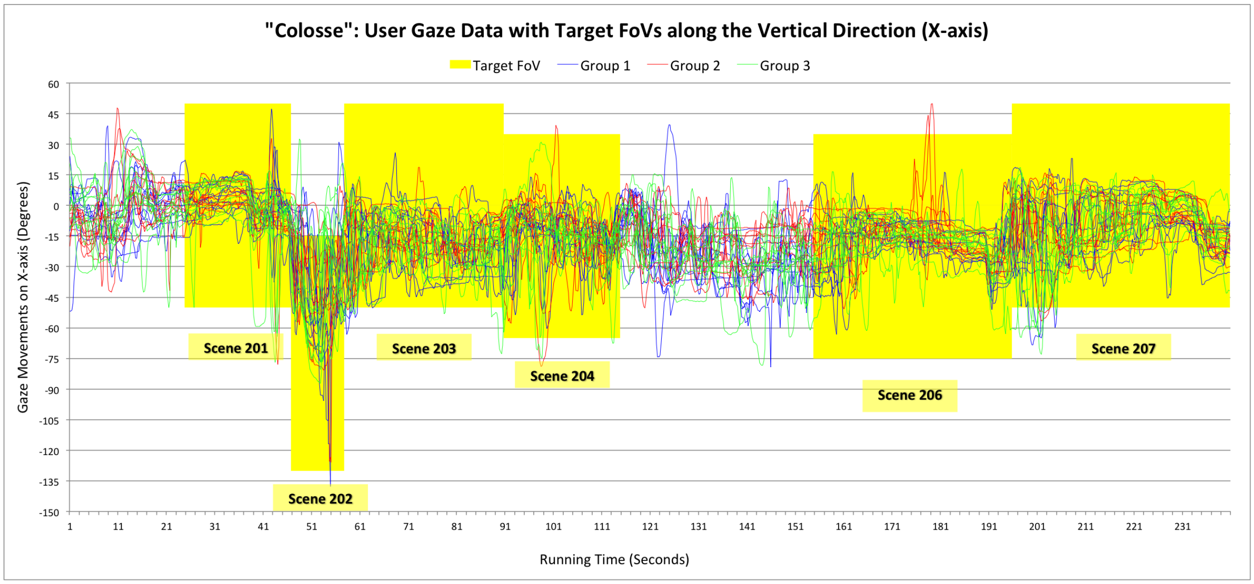

Figure 4.12: Gaze Data for *Colosse* (Pittom, 2016) along X-axis.

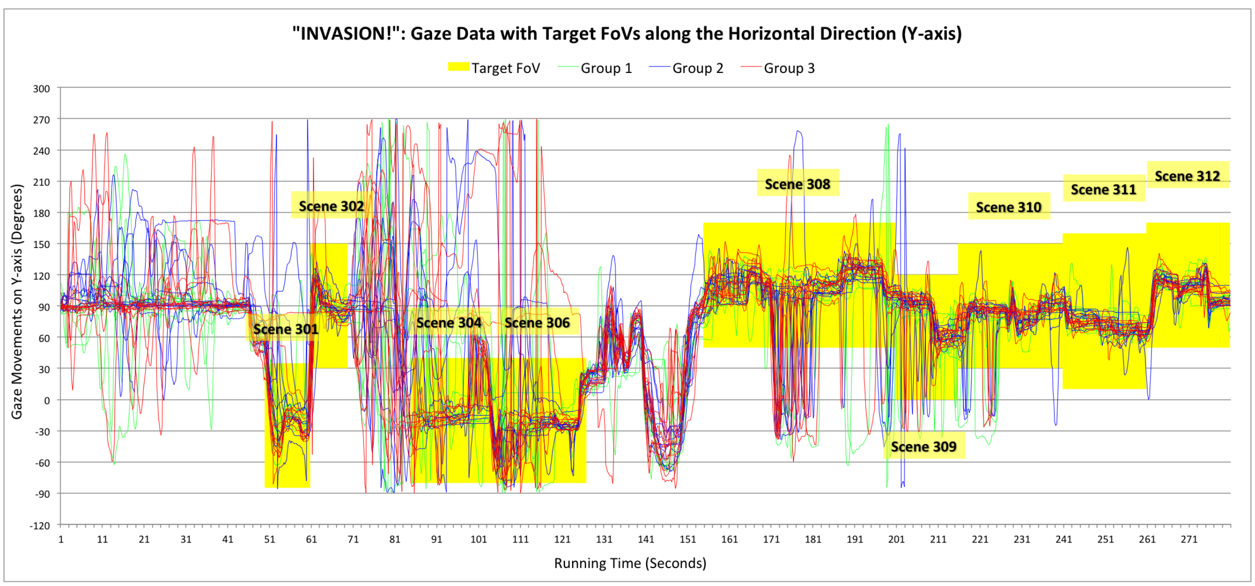

Figure 4.13: Gaze Data for *INVASION!* (Darnell, 2016) along Y-axis.

the total number of gazes that went out of the target FoV. Based on this, we calculated and analyzed the percentage of gazes that were outside of the FoV for each target scene, which we call "Gaze Error."

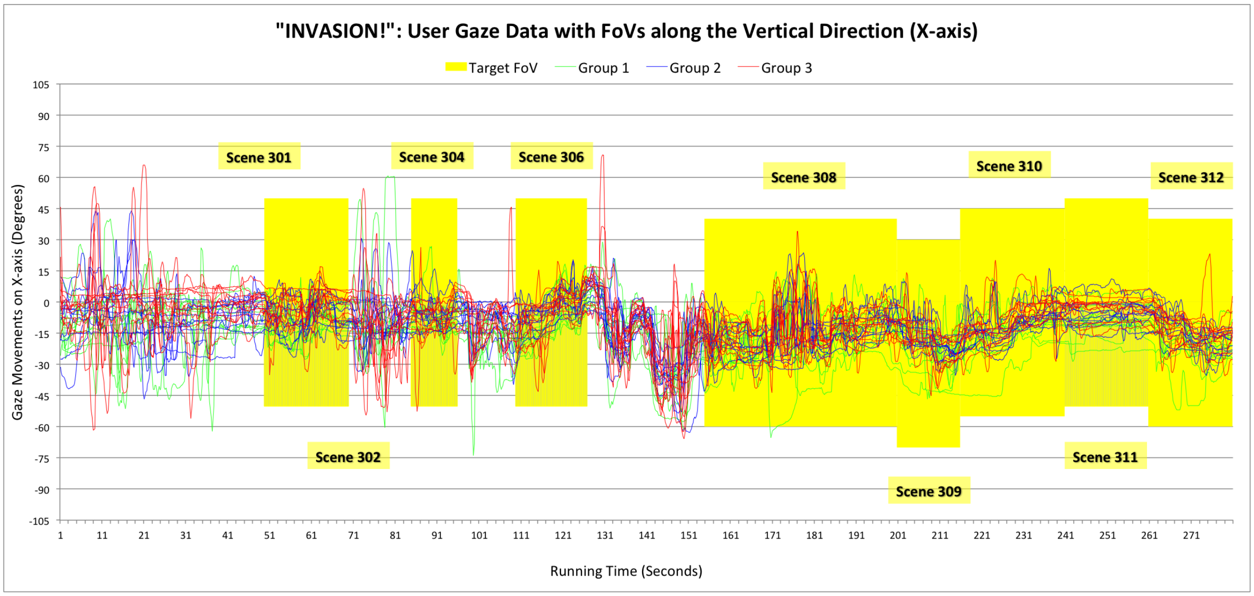

Figure 4.14: Gaze Data for *INVASION!* (Darnell, 2016) along X-axis.

4.7.1 Gaze Redirection with Virtual Character

Our first hypothesis stated that, in an interactive VR story experience without a character guide, if a virtual character guide is implemented, the user's gaze is more likely to fall on the target areas throughout the experience, and users are more likely to follow up with important story events. To test this hypothesis, we focused on analyzing the Gaze Error on Y-axis (the percentage of gazes that went out of the target FoV) for all the presented videos. As displayed in Figure 4.15, there are big differences in gaze behavior due to different VR stories, but it appears that the character conditions made extremely less difference. The results further indicate that all the guidance techniques used with *Rain or Shine* [28] had the smallest values, whereas all the guidance techniques used with *Colosse* [29] had the largest values.

In addition, a two-way mixed ANOVA result of the Gaze Error along the Y-axis suggests that there is a significant interaction between group and character conditions. $F(4, 54) = 67.76$, $p < 0.001$. This represents clear evidence that the movie assignments affected the gaze behavior. However, there were no significant primary effects for the group or condition factors individually. However, due to the confounding of the groups, we could not be confident when comparing character conditions from this test.

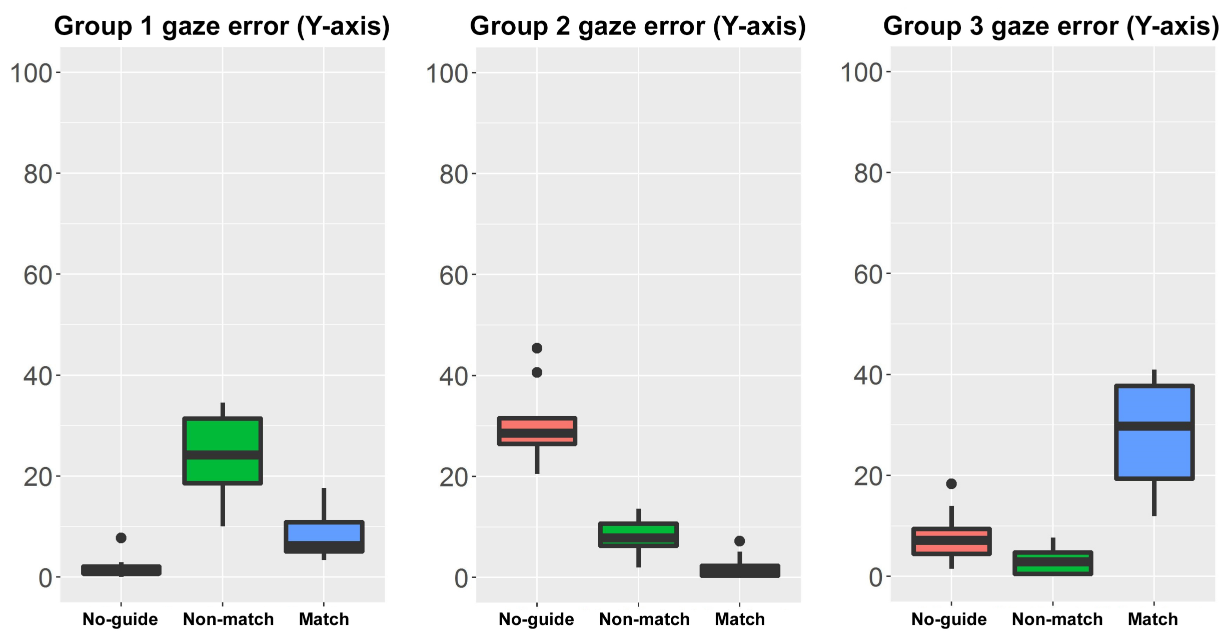

Figure 4.15: There are big differences on gaze behavior due to different VR stories.

4.7.2 Virtual Character and Art Style

Our second hypothesis stated that, in an interactive VR story experience with a character guide with a non-matching art style, if a virtual character guide that has a matching art style is implemented, the user's gaze is more likely to fall in the target areas throughout the experience, and users are more likely to follow up with important story events. Since the results in previous section are so heavily influenced by different videos, we considered the difference between each participant's Gaze Error and the median for the movie, which removed the variation based on the movie differences to allow the comparison of the character conditions more fairly. We normalized the results based on the overall median Gaze Error on Y-axis for each video. A one-way repeated measures ANOVA found $F(2,58) = 0.56$. The results show no evidence of significant differences due to character conditions; the three conditions are very similar. As Figure 4.16 below illustrates with the data analysis and normalization, we found no gaze differences between the different art styles.

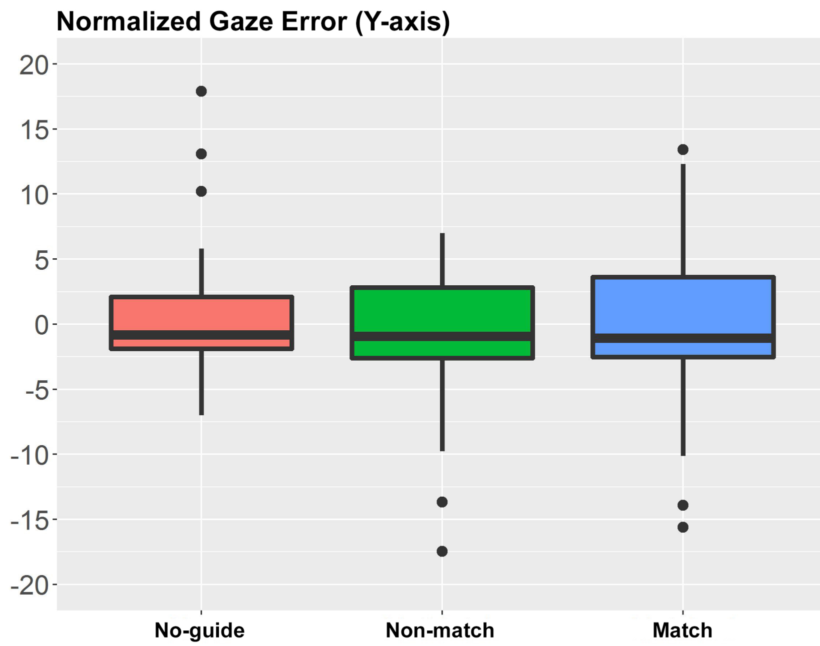

Figure 4.16: Gaze differences between character conditions for all presented videos.

Other than the quantitative data, we analyzed and summarized some interesting results from the interview responses. For example, some participants thought implementing a character guide that has a corresponding art style to the story was a contributing factor for their experience. They explained that the similar art style was more natural and made them believe that the character guide belonged to that specific story world. For these participants, if a character guide had a non-matching art style to the story, they would feel that the existence of the guiding character was unnecessary. On the other hand, some participants maintained that implementing a character guide that has a different art style to the story was more helpful, since it made the character guide stand out more from the background. In this case, the viewers felt that they were more likely to notice the guide and its redirecting movements. This was something that a guiding character with a matching art style could not achieve since it blended into the surrounding environment “too well,” leading it to become indiscernible.

4.7.3 Level of Enjoyment

Our last hypothesis stated that, in an interactive VR story experience with no character guide, if a virtual character guide is implemented, the user's level of enjoyment of the story will be enhanced. We tested this hypothesis by measuring the participants' ratings of level of enjoyment for each story experience. Based on the results of the post-study questionnaire, there was no concrete evidence that the participants'enjoyment level was affected by a character guide, nor did it indicate that the character's art style influenced their level of enjoyment.

In particular, we found that among all presented story experiences, *INVASION!*[32] got the highest average ratings of level of enjoyment no matter which guidance condition was applied. All participants (100%) were certain that they did enjoy the story. Within the video itself, the entertainment level is relatively higher when participants viewed the story with a matching character guide compared to the other two guidance conditions. In comparison, *Colosse*[29] had the lowest average ratings of 3.5 out of 5 points on the pleasure level regardless of which character guidance condition was applied. There were 20 out of 30 participants (67%) who responded with positive answers regarding whether they enjoyed the story experience. There was no difference of viewers' level of satisfaction regardless of whichever guidance technique was used. Last, 24 out of 30 participants (80%) answered "yes" when asked whether they enjoyed *Rain or Shine* [28]. Yet, when presenting this video without any character guide, the enjoyment level was found to have the highest average rating. On the contrary, participants' entertainment level reduced when watching this story with a matching character guide. Furthermore, the average enjoyment ratings for all videos under each guidance condition is very close. Table 4.1 below shows a detailed rating results on level of pleasure across different movies and guidance conditions:

According to the questionnaire, there are several possible reasons that could explain why a character guide did not contribute to the user's pleasure level: 1) The character guide made viewers less focused on the story events; 2) the character guide did not affect story development and therefore was unnecessary; 3) the character guide's art style did not match the presented story;

	Rain or Shine	*Colosse*	*INVASION!*	Average Enjoyment Rating
No Guide	4.2	3.5	4.6	4.1
Non-Matching Guide	4	3.5	4.5	4
Matching Guide	3.8	3.5	4.8	4.03

Table 4.1: Average ratings on level of enjoyment for each video presented under a specified guidance condition. The enjoyment level was rated on a 1-5 scale.

and 4) the enjoyment level was related to whether the user understood the story regardless of the guidance condition. For instance, 29 out of 30 participants (97%) answered that they were able to fully understand the story of *Rain or Shine* [28] and *INVASION!* [32], whereas only 11 out of 30 participants (37%) were able to fully understand the story of *Colosse* [29]. Additionally, during our interview section, we found that the participants' understanding of a story had little to do with whether they watched it with a character guide. Furthermore, even if some participants were able to memorize all the important focal events in the right order with the help of a character guide, they would still feel confused about a particular story.

4.7.4 Guiding Behaviors

As for the character guide's redirecting behaviors, regardless of whether the virtual character appeared in the form of a human or an animal, the guiding intentions for the horizontal direction worked well within a narrative VE. On the other hand, the guiding behaviors designed for the vertical direction did not work effectively as expected. Specifically, the length of time that the user's gazes stay outside a valid FoV along the X-axis was mostly not long enough to trigger the character's guidance animation for the vertical direction. Even if the guiding actions for the X-axis were triggered for a few times, many participants mentioned during the interview that they did not notice them. For instance, numerous users did not notice the fox jumping up or digging on the ground.

Additionally, the guiding body language designed for an animal character caused certain confusion, especially with the guiding intentions for the vertical axis. For example, the majority of the users reported that they did not understand what the meaning of "jumping" or "digging" was.

The reason was because we considered the character's directing behaviors as a part of its art style design. As explained previously, if we attempted to match the character's art style to its background story, the types of guiding behavior would be limited, especially for the animal characters. As a result, although the users reacted fairly quickly to certain instructional gestures such as pointing towards a direction, we could not simply have every animal character perform these types of human-like behaviors for the purpose of our experiment. Nevertheless, we found that having the animal characters turn their bodies to face a particular direction worked well for most participants.

5. SUMMARY AND CONCLUSIONS

In this work, we evaluated over 80 real-time rendered interactive experiences across different media. We divided all the reviewed contents into four categories based on their design objectives and presentation approaches. From these four major categories, we summarized the most-used methods, which directors applied to maintain a relative control when presenting a narrative experience in VR, that were associated with story-progression strategies and attention guidance techniques. The research objective is to construct a framework by summarizing and characterizing what has been achieved so far in order to overcome the VR storytelling challenge in the commercial domain with academic supports. Yet, we found during the media review that limited examples exist regarding the application of virtual characters among various guidance approaches in current storytelling framework.

Therefore, we considered a scenario wherein a virtual character would be helpful in facilitating user focus toward a target area within the narrative VE. We conducted an experiment examining the effects of a virtual character guide to redirect the user's attention in immersive VR story experiences because we wanted to contribute new knowledge to the existing storytelling framework. We expected to enhance the users' communication efficiency when receiving instructional messages from content creators via a virtual character guide. We also expected to raise the user's entertainment level of a VR story through building certain forms of emotional connection with a virtual character companion. For the study, we designed a method that allowed a separate virtual character to be overlaid on top of an existing 360-degree video and react based on the head-tracking data to direct the viewer to the core focal content of the story. Moreover, due to the issue of freedom for designers to add a detached character guide to an existing story, we focused on studying whether the art style of a character guide should match the story.

The motivation behind this thesis research is to study the discipline in depth and determine ways to assist directors in creating better story experiences in VR. The research is important because the future creators can follow the resulting framework and refer the experiment outcomes to develop better VR narrative experiences that are easier to follow and more enjoyable to watch.

5.1 Discussion

The experiment results demonstrate that the inclusion of a virtual character that was independent from the narrative had limited effects on users' gaze performances when watching an interactive story in VR. Furthermore, the implemented character's art style, despite of whether it matched or did not match that of the background environment, made very few difference to users' gaze performance as well as their level of viewing satisfaction. Nevertheless, through the study we conducted in this thesis, the character guide approaches still provided insights for future directors and designers into how to draw viewers' attention to a target point within a narrative VE, such as what could have worked well and what should be avoided.

One reason that no significant gaze difference was found with any character guidance condition could be due to limitation of the implementation design. Our design was to attach the character guide to the main camera's view-port; in this case, the character was visible in the bottom right corner of the user's field of vision in the HMD at all times. Even when users change their head orientation, the character guide would still follow and "float" in the corner of their vision. Although a few participants responded during the interview that they could ignore the character guide in the corner and just focused on the story content, others considered it to be quite distracting because it took their interest away from the background story. Since the character guide was always in sight at a fixed spot throughout the entire story-viewing experience, the effects of its guiding actions were restricted, as it was clearly unnatural and might even divert the users' attention.

Another reason was that the guiding body language designed for an animal character posed certain challenges for us. As pointed out earlier in the Literature Review chapter, certain gestures and postures such as pointing are common knowledge of the human societies. However, we could not simply have every animal character perform human-like directing behaviors if we were to consider their actions as a part of the art style design corresponding to its background story. For these characters, the types of guiding behavior were limited. For instance, even though having the animal characters turn their bodies to face a particular direction worked for most participants, numerous users reported after the experiment that they did not understand what the fox guide was trying to convey when it was “jumping” and “digging”.

Lastly, it was hard to conclude the gaze focal points of the users solely by tracking their head orientation. As mentioned earlier, the character guide was stuck to the bottom corner of the user’s HMD view-port, and some users were able to ignore the character guide while others were not. This implied that there was a possibility that the change of some head orientation data was associated with certain story elements (such as sound cues) in the background instead of the virtual character’s guiding action.

There are several alternative design factors that may help to make the character guide technique feasible for future study. One option is to create the virtual character in a form of a flying creature so that it makes more sense even if it is “floating” with the user’s vision. In addition, we may have the character guide become less visible when the user is looking at the expected regions within the VE. For example, 1) The character may hide a portion of its body somewhere outside of the headset’s view-port; 2) the character may turn to a shadow profile, as if it was another audience that the user would normally see in a theater; or 3) giving audience the choice of turning on or off the character, so that they would feel less bothered whenever they don’t need its guidance.

As far as the experimental design, it is important that we train the users to read and understand a character’s postures and its guiding intentions. This can be done by showing them a short demo with a practicing session before presenting a story. In this case, no matter how creative the character guide’s actions are designed, the audience will not feel confused about them. In addition, if possible, we should test the character technique with an eye-tracking system to find out the user’s gaze focus more accurately. Finally, we need to further test the character guide technique in a constructed VE rather than placing it in a 360-degree video playing in the background. The guiding behaviors of the characters will be more natural if they can move within the environment, which may lead to better gaze performances when viewing a VR story.

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APPENDIX

Experimental Design Groupings

	Video 1: *Rain or Shine*	Video 2: *Colosse*	Video 3: *INVASION!*
Group 1	N/A (no guide)	girl (non-matching)	rabbit (matching)
Group 2	girl (matching)	N/A (no guide)	fox (non-matching)
Group 3	rabbit (non-matching)	fox (matching)	N/A (no guide)

Table 5.1: Specific groupings of videos and guides used in the experiment

Video Setup in Unity

The three videos we prepared were either provided by the directors or downloaded from the internet in 4k or the highest resolution possible for best visual results. We set the videos up using the panoramic video features in the Unity Editor [7], so that viewers can watch the stories in VR, experiencing the world of the story in a 360-degree environment via head mounted displays (HMDs). Since Unity supports equirectangular layout (longitude and latitude) for 360-degree videos, we first needed to re-encode two of the videos into the standard equirectangular panorama projection for Unity to recognize.

The videos in recognizable format were then imported to Unity as assets, and a Video Player component was created so that each video could be played full-screen by the default camera. By switching the Render Mode option in the Video Player, the videos were played to a Render Texture, this helped us edit specifically how the video should be displayed. Next, We created a new Material with the Skybox/Panoramic Shader to receive the Render Texture. This step was to replace the default Skybox with the video content. Lastly, we connected this newly established Skybox Material to the Scene via Lighting Settings. This final step made sure that the imported videos could be rendered and played as a backdrop to our Scene, in which we implemented the character guides and set up corresponding lighting.

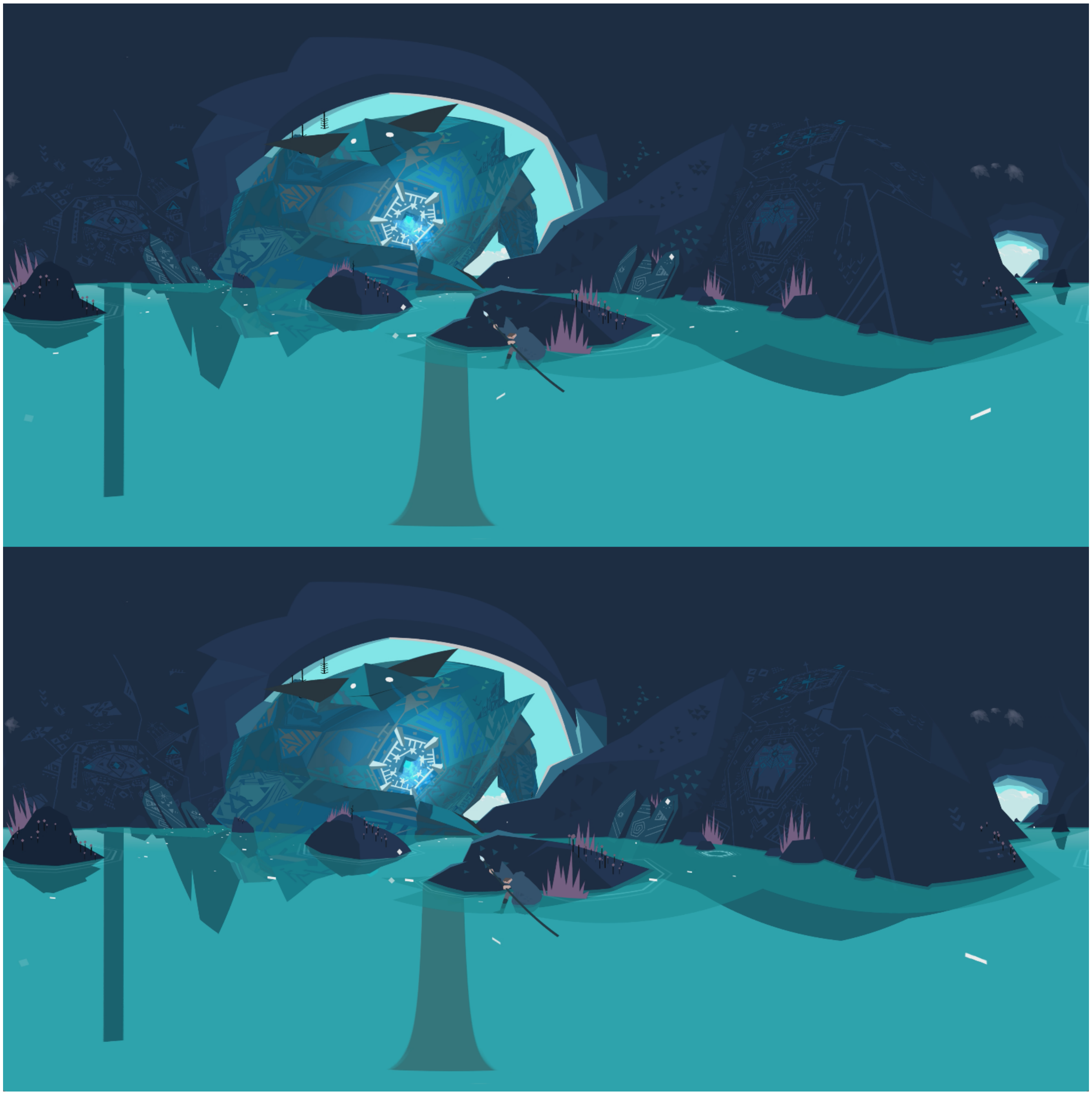

Figure 5.1: A screen-shot of the over/under equirectangular layout for the 360-degree video of *Colosse* (Pittom, 2016).

Interview Question Examples

1. Could you describe what each story is about? Please try to memorize the order of important events happened in the story.

2. Did you feel like the character guides helped you in following along the major events of each

story? In what ways?

3. Did you feel like the character guide's art style/general appearance was a big contributing or disturbing factor for your experience?

4. Other than the art style, could you elaborate on any other aspects of how the character guides affected your experience?

5. What types of guiding animation worked the best in your experience? What didn't work well?

6. In the previous questionnaire, you answered that you would/wouldn't prefer to have a character guide in other VR story experiences, why is that?

7. Do you have any suggestions on how we might improve the design of a character guide as a gaze redirecting technique?

Target Scenes and Expected FoVs

We have included detailed illustrations of all movies' target scenes with corresponding time periods as displayed in Figure 5.2, Figure 5.3, and Figure 5.4 presented below. These figures also demonstrate a visual description of the user's head orientation in relation to each target scene as well as a corresponding event screen-shot:

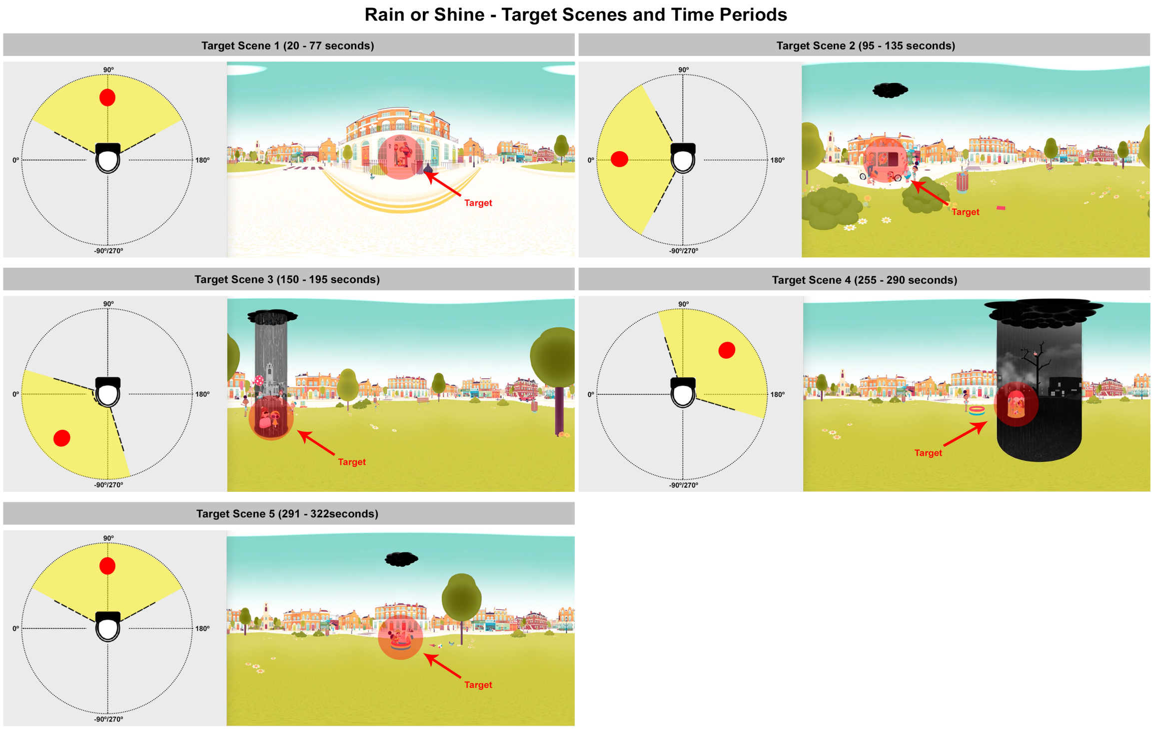

Figure 5.2: *Rain or Shine* (Massie, 2016): target scenes with valid FoVs and screen-shots of the occurring events.

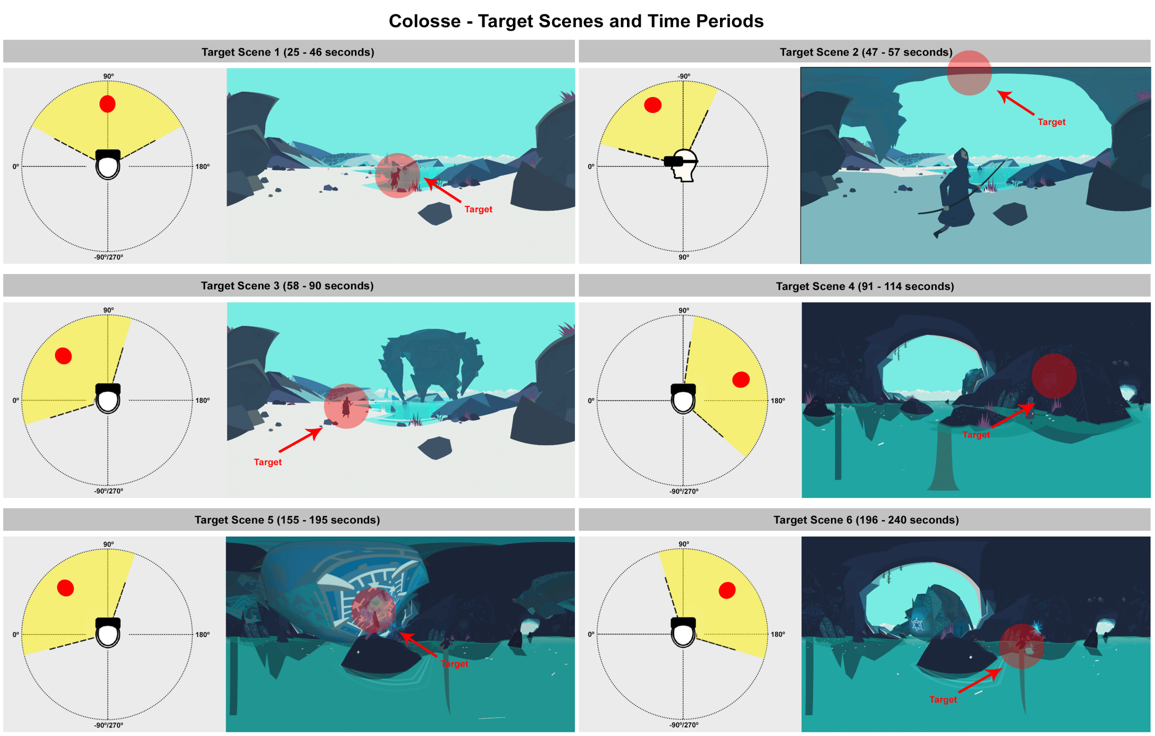

Figure 5.3: *Colosse* (Pittom, 2016): target scenes with valid FoVs and screen-shots of the occurring events.

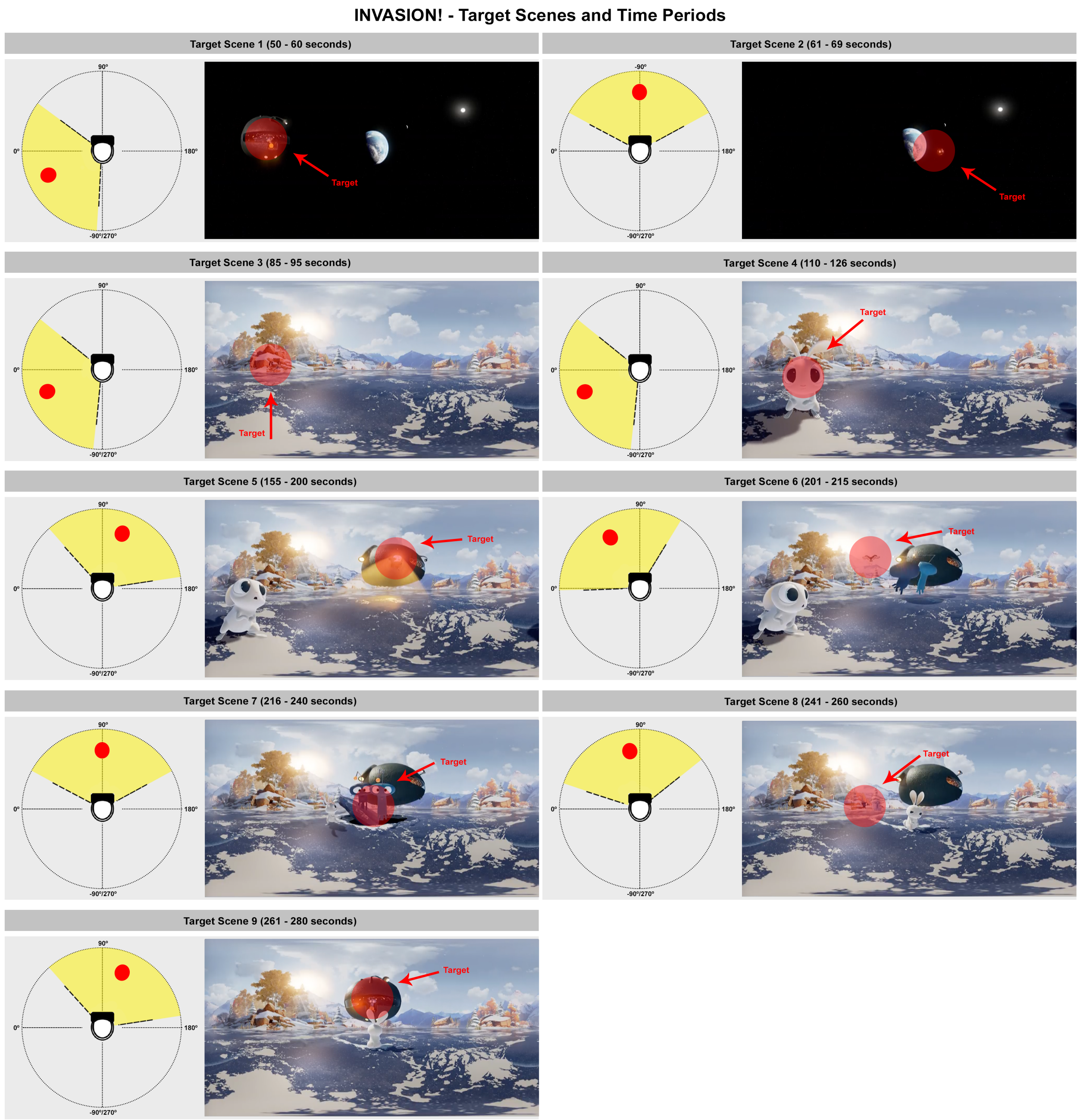

Figure 5.4: *INVASION!* (Darnell and Hawke, 2016): target scenes with valid FoVs and screenshots of the occurring events.