EXPLORING VIRTUAL PRODUCTION:

Achieving High-Fidelity Cinematic Imagery on a Budget

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1. Introduction

One could talk about the cinematography industry almost endlessly, from its starting ages dating back in the late 19th century until this day and age. The evolution of productions that started as silent, colourless short films, to the era of fully developed motion pictures with budgets up to the nine digits (Reid, 2023), hundreds or even thousands of crew members, with multiple cross-department collaborations, massively complex schedules, logistics, and planification. All these factors usually fall behind the scenes where the general audience may struggle to fully understand what the reality of the filmmaking process entitles.

For nearly a century, filmmaking was purely practical with no use of computer aided techniques until 1973 when the movie Westworld was released showcasing the first scene that made use of Computer-Generated Imagery, CGI, (Formichella, 2020). However, the introduction of elements in film was quickly discovered with visual effect techniques such as double-exposure mattes, black mattes, and traveling mattes, invented in 1898 by the British filmmaking pioneer George Albert Smith (Leeder 2017, pp. 67-95, as cited in Pires et al., 2022, p. 20). The film industry quickly began to develop and expand its practical techniques until the 60s, when colour difference travelling matte was invented. This technique eventually led to the first computer-aided procedures also known as chroma keying or green screen effect (Pires et al., 2022, p. 20).

The Virtual Production Glossary (2023) defines chroma keying as “a keying technique that allows one to separate an object from its background based on colours that are unique to either the foreground or background.”

Computer-aided techniques have also evolved fast. Nevertheless, chroma keying through blue or green screen has still been the main procedure until this day and age. In recent years, the quality and complexity of chroma keying has massively increased with the exponential innovation of technology in the past decades. The desire of filmmakers to immerse the audience in the story through various audiovisual approaches has also increased, thus new ways of compositing have also emerged. To minimise time-consuming rendering and multiple layers of content replacement to achieve final picture, the exploration of real-time techniques commenced (Pires et al., 2022, pp. 20-22).

Real-time compositing and Virtual Production came to light with the improvement of real-time engines such as Unreal Engine (Kadner, 2019, p. 7), which allowed high-quality imagery to be captured live and in-camera on set, such as within an LED volume. This type of Virtual Production is commonly known as ICVFX, In-Camera-Visual-Effects (The Virtual Production Glossary, 2023).

1.1 Defining Virtual Production

Virtual Production is a term in the film industry that encompasses a variety of filmmaking methodologies that include a wide spectrum of computer-aided productions and visualisation techniques.

Zwerman and Okun (2024) define Virtual Production as “the augmentation of traditional visual effects or animation workflows by the use of real-time, digital technology” (p. 5). This definition encompasses a large range of existing implementations. Therefore, one should consider additional explanations for this term.

> A few notable definitions about Virtual Production. Weta Digital states that “Virtual production is where the digital and physical worlds meet”. Moving Picture Company (MPC) adds to this definition with more technical detail: “VP combines virtual and augmented reality with CGI, Computer-Generated Imagery, and game-engine technologies to enable production crews to see their scenes unfold as they are composed and captured on set” (Kadner, 2019, p. 3).

Another definition for Virtual Production (Pires et al., 2022, p. 20) “[…] it essentially consists of a method that uses a suite of software tools to combine live action footage and computer graphics in real-time, generally through large stages with LED walls creating a sophisticated virtual filmmaking environment.”

The definitions mentioned in the field guide by Kadner were a great starting point for the purpose of this study. It is worth highlighting the explanation that MPC adds, as they refer to CGI and game-engine technologies, which are the main tools used for the methodology phase of this report. Additionally, another key point is enabling the crew to see the scenes unfold live on set.

Pires et al., (2022, p. 20) mention LED walls in their definition, which is essentially where the CGI and game-engine content ends up displayed to be captured on camera. LED walls are a key element in Virtual Production thus are also worth explaining in further detail.

LED walls, also known as LED volumes, as shown in Figure 1, refers to large plane surfaces created by a chain of smaller panels made up of light emitting diodes that display visual content as if it were a computer monitor. Depending on the complexity, budget, and space availability, production companies often build their own LED volumes ranging from a surface of a couple of square meters up to even hundreds of squared meters. These volumes are usually curved, oval shaped, or dome shaped to account for the cone shaped field of view of

the camera and to surround the subject as much as possible for a better immersion with the content displayed on the volume.

Figure 1

LED wall or LED volume

Note. Oval shaped LED volume stage set up. From *1899*, by Netflix, 2022. *(https://youtu.be/ZMynJCgJIQk?si=8na1XTsP4gyh-2Cn)* Copyright 2022 by Netflix Production Technology Resources.

1.2 The Problem in Traditional Filmmaking

Nowadays, many films make use of complex production processes that require multiple technology and science departments to collaborate in a short amount of time (Priadko & Sirenko, 2021, p. 53). In modern filmmaking, production companies have been trying to reduce this amount of time to minimise expenses. In the traditional filmmaking process, productions are usually developed in a linear manner, in which the sequence of stages includes the initial development on paper, the pre-production phase, the production phase, and finally the post-production phase.

> For moviemakers, the main problem is uncertainty. When the director of photography has to guess the colour of the lighting so that it matches the invisible element of the green screen, or a director does not know exactly what the virtual character of his film will actually look like, that is uncertainty (Priadko & Sirenko, 2021, p. 54).

As a result of all these aspects, filmmakers have it difficult to achieve a final version of a scene, and the result often comes with some creative compromises.

Usually, the completion of a given scene in a film requires many steps, and often uncompleted or temporary clips are replaced with their final versions. Colour correction, visual effects, sound layers, and other elements are also added to achieve the desired result. Consequently, filmmakers must make tough decisions in the process of completing a scene, which often ends up with some creative compromises upon the release of the film (Priadko & Sirenko, 2021, p. 54).

When looking at traditional forms of previsualisation in the pre-production phase, Kadner (2019) explains that there is margin for improvement. Traditionally, previsualisation has been made with animation software developed for premium image quality at the expense of long rendering times. Artists have to work with versions that are neither of optimal image quality nor real-time malleable. Kadner (2019) argues that this can result in filmmakers feeling disconnected from a supposedly collaborative process, and the leveraging of the talents of the department heads ends up not being fully optimised.

Additionally, Kadner (2019) mentions that traditional visual effects workflows can affect the scale and scope of a production. Streaming platforms have increasingly upped their ambitions which cannot always match the complexity of major production releases. “This is due in part to cost but also to the realities of network release schedules, which only allow for a certain degree of spectacle to be created within the allotted time frame” (Kadner, 2019, p. 5).

1.3 Research Question

When observing the current state of visual effects workflows, obtaining a high-fidelity final image in heavy VFX based filmmaking can be challenging, especially when working with restricted resources. This research explores the potential that Virtual Production can offer on a small-scale with a limited amount of budget, time, and crew. The main problem relies in the fact that Virtual Production is still an innovative and expensive workflow for most cinematographers, thus making it a rather hard to access filmmaking tool. This leads to the main research question:

RQ: Can Virtual Production filmmaking, utilising LED volumes under resource constraints, yield final images comparable to those in feature-length films?

The answer to this question is of high relevance for the industry for various reasons. Virtual Production filmmaking with real-time computer-generated imagery on LED volumes is a modern and fairly new workflow that recently emerged as a result of advances in real-time

computer graphics, which made Virtual Production more accessible for filmmakers (Kadner, 2019). Thus, research in this field is scarce and the need to explore the capabilities of Virtual Production are still an ongoing process in the film industry. Also, Kadner (2019) argues that Virtual Production has the possibility of eliminating the challenges that come with budgeting, scheduling, and developing time, enabling smaller-scale and indie filmmakers to obtain imagery on par with blockbusters. Confirming this statement is of high importance for the advancements of this new workflow, as achieving these results in small-scale productions would allow indie filmmakers to learn the fundamentals of the process of Virtual Production, which can only be further expanded to a larger scale where improved final outputs would be obtained.

2. Literature Review

2.1 Introduction

This literature review is divided into three main sections. The existing literature, the research parameters, and the hypothesis of the study.

In Section 2.2 the existing literature is presented starting with what the main benefits and potential of Virtual Production are, as well as its challenges and limitations. Followed by a brief explanation of the different practises that are publicly defined in Virtual Production. Finalising with how authenticity is measured in audiences and its application to cinema.

In Section 2.3 the research parameters for this study are presented. Starting with the introduction of the resources available for this study and an explanation of the involvement and experience of the author in Virtual Production. After that, the definition of experimental reproductions that were adopted for this research, followed by a selection of three movies that the author argues would benefit from Virtual Production based on the findings of the existing literature.

In Section 2.4.1 is presented the hypotheses formulated to answer the research question.

2.2 Existing Literature

2.2.1 The Benefits and Potential of Virtual Production

Multiple sources conclude that the main advantage of utilising Virtual Production with LED walls is that the uncertainty of the usual pre-production and visual effects production is replaced by working images close to the end result (Pires et al., 2022; Priadko & Sirenko, 2021; Kadner, 2019). Because these high-quality images are created in real time, iteration and experimentation are simplified, more cost-effective, and flexible (Kadner, 2019, p. 7, Priadko & Sirenko, 2021, p. 54).

> It has been established that the live view of composited elements on set, be it in final pixel quality or in a proxy resolution, is one major advantage of virtual production for filmmakers. Real-time render engines reduce the level of uncertainty linked to visual effects productions and remove many creative limitations that once compromised directors and film crews. Camera operators receive live feedback to perfectly frame all shot elements, production designers can instantly adapt computer generated

> images to on-set props and actors and stunts become safer and more controlled than if shot in real locations (Pires et al., 2022, p. 24).

Kadner (2019) also argues the following:

> All of these efficiencies and increased image quality offer a trickle-down effect to more modest and tightly scheduled productions. By leveraging virtual production techniques with a real-time engine, network series, streaming productions, and indies can all achieve very high-quality imagery and epic scope. A real-time engine has the potential to eliminate many of the bottlenecks of budgeting, schedule, and development time that can prohibit smaller-scale productions from producing imagery on par with blockbusters (p. 8).

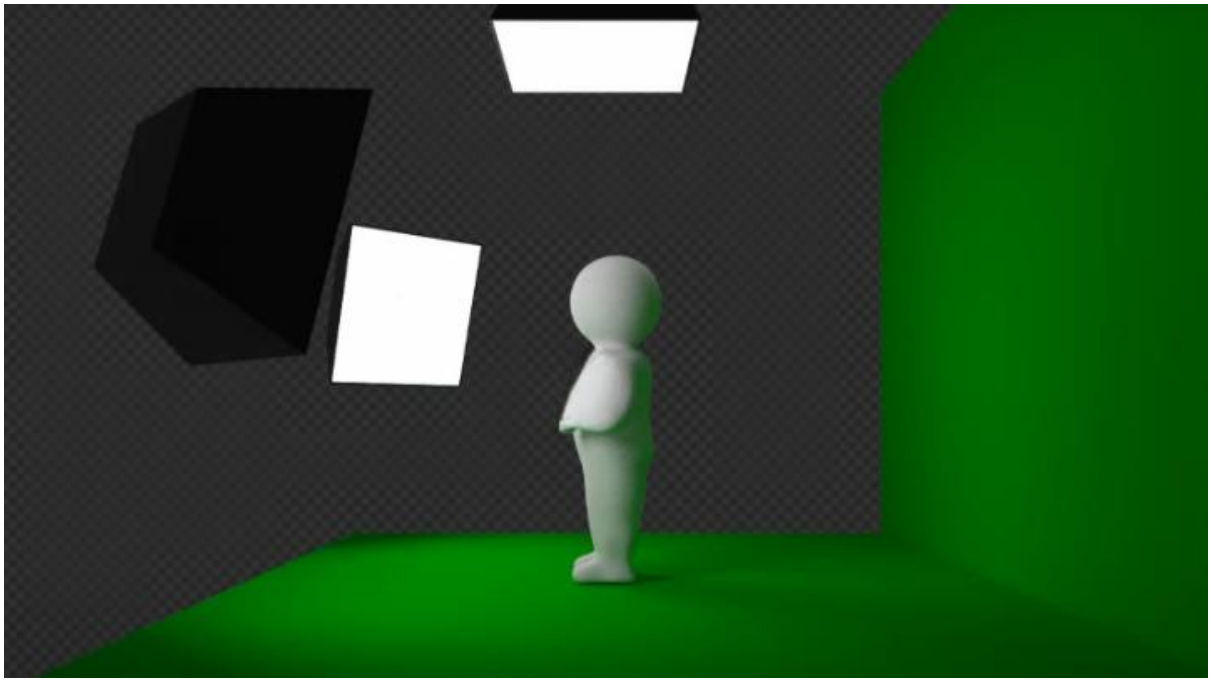
A different perspective from Fair (2023) argues that Virtual Production offers great economic and environmental advantages. This new process encourages filmmakers to return to the studio rather than location-based filming, which allows productions to take place in a controlled environment. Filming in a studio means that traveling out large crews to remote locations and dealing with unstable weather and sound can be taken out of the equation. “House of the Dragon was based just outside of Watford, despite using many similar locations to the original Game of Thrones series, which was filmed in Northern Ireland” (p. 51).

Fair (2023) states that the convenience of Virtual Production will become a significant mode of production in the upcoming years, highlighting the global Pandemic which showed evidence of the benefits of filming in a controlled environment. In addition to the travel saving costs that Virtual Production provides, its core advantage lies in its effectiveness over green screen in particular contexts. “[…] when the background is reflected on costumes or props and does not require onerous amounts of post-production fixes” (p. 52).

The main burden that comes with green screen is what is known as green spill, as seen in Figure 2, which is the colour of the background bouncing off and reflecting on the surfaces on set. Large amounts of time and budget goes into post-production work to remove it. On the contrary, Virtual Production solves this problem since its background already gives off the correct reflections that will be seen in the final picture.

Figure 2

Green screen representation



Note. Example of how light bounces off the green screen and reflects on the subject. From *Reducing Green Spill – for photography,* by Pixnub, 2017. *(https://youtu.be/EYDg2yz0_EE?si=PEhTz98bCBW1PJ3M). Copyright 2017 by Pixnub.*

Additionally, the environmental impact of Virtual Production is worthy to discuss. Despite its expensive technology and power consumption it could be argued that it is an innovative solution to reduce the carbon footprint of productions that require traveling to distant locations. In 2021, in the United Kingdom, the first carbon neutral Virtual Production short film was produced (Miller, 2021). “The short film was shot in just one location in London, with the action virtually taking place in ten different areas - such as the Scottish Highlands and streets of Japan.” Miller (2021) also claimed that the entire production emissions were less than one tonne of carbon, which was offset, compared to the estimated 120 tonnes that would have been produced without the use of Virtual Production.

A study conducted by Schulz et al. (2021) about the advancements of digitalisation and its implications for the value chain in the industry predicted what would be expected over the next decade in the motion picture industry. The research conducted an international two-stage Delphi study consisting of two survey rounds by an international group of experts from the film industry.

Schulz et al. (2021) forecasted that over the next decade “complex movie sets will be digitally created for actors to perform in them live and without further post-production” (p. 408). Besides, they claim that the industry might include greater power allocation to IT companies and further new entrants of digital technologies, which will transform movie productions to be both simpler and more complex. This will also affect camera manufacturers, production designers, and actors in their need to stay in the industry. Similarly, Schulz et al. (2021) argue that “video game producers already have multiple competences future movie making might require” (p.409).

The findings of Schulz et al. (2021) directly correlate with how the Virtual Production realm has shifted the film industry to include more virtual sets that save post-production costs. As well as making film productions simpler, though at the same time adding more complexity by introducing many new technologies and workflows.

2.2.2 Addressing Virtual Production Challenges

Zwerman and Okun (2024) argue that the main disadvantages of Virtual Production are its steep learning curve with its growing technology and evolving workflow where a combination of the filmmaking industry and the videogame industry is required which inevitably adds more complexity. These massive industries are rapidly evolving as technology advances faster each day and filmmakers must be able to keep up if they want to pursue this workflow.

Sott Chambliss, Production Designer for Guardians of the Galaxy, Vol. 2 states that Virtual Production is not precisely adequate for every genre in the film industry. Scripts set in the present day that require interaction with the environment of the story such as Mission: Impossible, or Bond movies would rarely benefit from this technology. Furthermore, Chambliss argues that accessibility for this technology is hard to find due to its large expenses related to both the stage set up and the development of the assets required for playback (Hogg, 2021a).

Virtual Production is not the solution to every filmmaking challenge. There is a time and place to maximise the use of this workflow over other solutions.

As stated by Zwerman and Okun (2024), Virtual Production given its current technological limits would suit best for sequences that make use of entire digital characters and digital environments, situations that are cost prohibitive or when a film set is too challenging to recreate physically, or too inconvenient to shoot on location. An example of this would be Alter Ego (2021). This production integrated digital characters on set with a panel of judges that could interact with them verbally as well as visually.

Scenes with predominantly fabricated environments are also perfect for virtual production. As an example, one might consider The Batman (2022) from Warner Brothers. This production made use of virtual production for various sequences: A car chase sequence, see Figure 3, and a sunset rooftop sequence stand out as two unique use-cases for the same virtual production solution (Zwerman & Okun, 2024, p. 11).

Figure 3

The Batman, 2022, behind the scenes

Note. Car chase scene filmed with an LED volume. From *The Making of The Batman – The Batman,* by Matt Reeves, 2022, Warner Brothers. *(https://youtu.be/2kQzfng264w?si=x0UahuD60FQPcTUU).* Copyright 2022 by Max.

The rooftop sequence from The Batman (2022), as seen in Figure 4, is worth highlighting for two main reasons. On the one hand, the production crew was able to shoot the sequence without concern of the passage of time “the lighting for any shot remains unchanged in a virtual environment, unless one would like to change it” (Zwerman & Okun, 2024, pp. 11-12) Additionally, artistic modifications such as the positioning of the sun or clouds would be possible with no major inconveniences and could be done on the fly by a Virtual Production operator. On the other hand, the universe within the movie is visually distinct from any real-

world location. Filming it physically would require significant pre-production work for location scouting, permits, and travelling cast and crew. Significant post-production work would also be required to obtain the desired final film look (Zwerman & Okun, 2024).

Figure 4

The Batman, 2022

Note. Rooftop scene filmed with an LED volume. From *The Batman,* by Matt Reeves, 2022, Warner Brothers. *(https://irs.www.warnerbros.com/gallery-v2-jpeg/movies/media/ajax/fieldytvideos/und/form-jwjf-3nm0lidwwfptrjddj6fgeoxv8tbpewkmx0lro/tbm-trl2-88772.jpg). Picture – TM & © 2024 Warner Bros. Entertainment Inc. All Rights Reserved.*

Other practical limitations when filming with an LED volume must be considered, such as fast camera movements, wide shots, or high angles are limited by the space constraints of the LED volume. As well as the tracking system latency might limit the speed of the camera moves or shakiness of extreme handheld shots. The camera has limited frame rate options due to the refresh rate of the volume, which must be synchronised to the camera. The focus of the camera should not be on the volume to avoid capturing its individual pixels, the appearance of any unwanted artifacts, flickering, or moiré patterns. Background actors and other digital characters can be problematic to produce in high fidelity. Moreover, LED volumes can reflect sound which can cause challenges to record audio, as well as introducing colour shifts on skin tones due to the nature of the LED lighting (Zwerman & Okun, 2024).

Adam Myhill, Creative Director of Labs, Unity Technologies also discussed the need for more accessibility in the future for Virtual Production:

> Now that the industry understands how real-time technologies can best benefit a production, the next step is making them accessible to every level of filmmaker. There is no reason that a student making his first film shouldn't be able to benefit from the same kinds of real-time production tools as Jon Favreau and Steven Spielberg. Throughout 2020, we also saw the emergence of a different type of democratization powered by real-time productions – the democratization of location (Hogg, 2021a).

The importance of accessibility of Virtual Production tools is imperative for the industry to be able to expand, as well as to allow new and upcoming filmmakers to enter in the Virtual Production field. This would enhance and reveal the potential creative possibilities that Virtual Production offers.

2.2.3 Virtual Production Types

Virtual Production has a variety of different applications, spanning from live green screen replacement to full digital replacement of actors, environments, and even cameras (Zwerman, S., & Okun, 2024). Kadner (2019) goes into detail about the different types of Virtual Production that use real-time engines as their key work tool. These methods of Virtual Production include visualisation, performance capture, hybrid Virtual Production, and in-camera Virtual Production.

2.2.3.1 Visualisation

Visualisation can be defined as "prototype imagery created to convey the creative intent of a shot or a sequence" (Kadner, 2019, p. 12). It could be argued this is the most familiar use case for most filmmakers. There are a number of different forms of visualisation, however, the most used in Virtual Production is what is known as Previs. In short, Previs is a more advanced form of storyboards and animatics where filmmakers are able to experiment with different staging and art directions to have a closer look of the final sequences.

2.2.3.2 Motion Capture

Motion capture, or performance capture consists of tracking and recording the movements of objects or actors and translating those movements to a digital animated model. When facial expressions are recorded, its often known as performance capture (Kadner, 2019).

2.2.3.3 Hybrid Virtual Production

> Hybrid virtual production is the use of camera tracking to composite green screen cinematography with CG elements. This is created either as a live preview for the director of photography and the camera operator, and completed in postproduction, or is intended as final pixel in camera (Kadner, 2019, p. 16).

2.2.3.4 In-Camera Virtual Production

Lastly, what Kadner (2019) refers to as Live LED In-Camera Virtual Production, as its name suggests is “the use of image output from real-time engines to a live LED wall in combination with camera tracking to produce final-pixel imagery, completely in camera” (p. 17). Previous advancements in the realm of Virtual Production have led to the development of this final form of Live LED in-camera filming. Zwerman and Okun (2024) believe that the adoption of real-time green screen substitution is currently one of the most promising aspects of Virtual Production in modern media discussions. Zwerman and Okun (2024) define this form as rather than a traditional green screen, an LED wall is used to replace the material environment. “Operators can transmit final-frame 3D imagery to the wall in real-time, allowing the cast and crew to become immersed in the space, both story-wise as well as physically” (Zwerman & Okun, 2024, p. 5).

Additionally, a production context article from Netflix Studios (n.d.) distinguishes the difference between 2D In-Camera VFX, Visual Effects, and 3D In-Camera VFX when it comes to displaying content on an LED surface.

2D In-Camera VFX refers to the displaying of pre-rendered footage in a fixed perspective through an LED volume. This allows for more realistic and high-quality footage to be captured on camera. For driving scenes for example, the real driving footage is captured previously from a variety of cameras and angles. The footage is later reprojected on an LED volume in an easily repeatable and controlled environment (Netflix, n.d.).

3D In-Camera-VFX, similarly as Kadner (2019) describes it, is the use of real-time engines to generate the imagery displayed on a LED volume. This method requires camera tracking synchronised with the real-time engine to capture the 3D generated content. The main distinction with 2D In-Camera VFX is that the 3D generated environment is not rendered into a final video format, instead, the real-time engine allows the displayed content to be modified in real time (Netflix, n.d.).

At the time of this writing, the resources and equipment utilised for this study made possible to adopt the process of using real-time engines to generate the content displayed on the

LED volume, with the use of camera tracking systems synchronised with the real-time engine, to capture the footage as ICVFX. Section 2.3.1 explains the resources and their specifications in more detail.

Kadner (2019) argues that this method leads to less uncertainty for the production cast and crew since everyone can see the content of the background live on set. Zwerman and Okun (2024) add that in terms of story, LED walls enables filmmakers, directors, and actors to have a shared sense of diegetic space, meaning the fictive space in which the characters live and act. Furthermore, it helps the crew to achieve more coherent and dynamic decisions on set, resulting in a more refined camera movement that might not otherwise be properly executed if environments were to be added in post-production.

Before Virtual Production evolved into its state-of-the-art form that is known today, one could look back at movie features that could have benefited from utilising this new way of filmmaking. It could be argued that a multitude of films that were shot in the traditional VFX and CGI workflow would have taken advantage of the tools that Virtual Production offers if they were to be produced in the present day. Many science fiction movies, or other genres that required fictitious and impossible to recreate locations and environments would be able to be filmed more time and cost efficiently. Some examples one could explore include Gravity, 2013, Interstellar, 2014, Arrival, 2016, Pirates of The Caribbean film series, 2003-2017, All Quiet on the Western Front, 2022, and many others.

2.2.4 Measurement of Authenticity in Cinema

A study conducted by Radbourne et al. (2009) measured the quality of audience experience in performing arts. They explored four components of the audience experience, knowledge, risk, authenticity, and collective engagement. A relevant component that could be applied for this research is authenticity. Radbourne et al. (2009) explain that authenticity can be seen in two main parts. Authenticity of what is being offered “Is the performance up to technical standards? Does the audience believe the play is by the playwright whose name appears on the program? Is the music performance faithful to the score?” (p. 20). And the emotional perception of the audience “generally associated with reality, truth and believability” (p. 20).

Another study from Bayo-Moriones et al. (2018) conducted a quantitative survey research about the audience perception of quality television in Spain. A sample size of 418 respondents to their questionnaires provided them with the data collection to assess the meaning of quality television. The study approached the surveys by asking the respondents to rank ten different characteristics that in their opinion best defined quality television. Bayo-Moriones et al. (2018) followed Myers (1999) theory (as cited in Chrzan & Golovashkina, 2006) that explains how “in the absence of constraints, or any need to make trade-offs,

respondents can (and often do) give all attributes high importance ratings, so that the responses for all attributes tend to bunch up towards the positive end of the rating scale" (Chrzan & Golovashkina, 2006, p. 719).

Measuring quality perception in a quantifiable manner on any entertainment medium whether it is in performing arts, or any form of media or audiovisual material is rather subjective. As Radbourne et al. (2009) explain, the perception of each individual in the audience is affected by many variables, meaning that each individual perceives it in a different way. Additionally, all forms of entertainment are different from each other, and some are more successful than others, which is a challenging factor to predict and only known to the creators once the final product is released to the public. Nevertheless, Radbourne et al. (2009) and Bayo-Moriones et al. (2018) confirmed that quality perception on audiences in the entertainment industry can be measured in multiple forms and levels.

2.3 Research Parameters

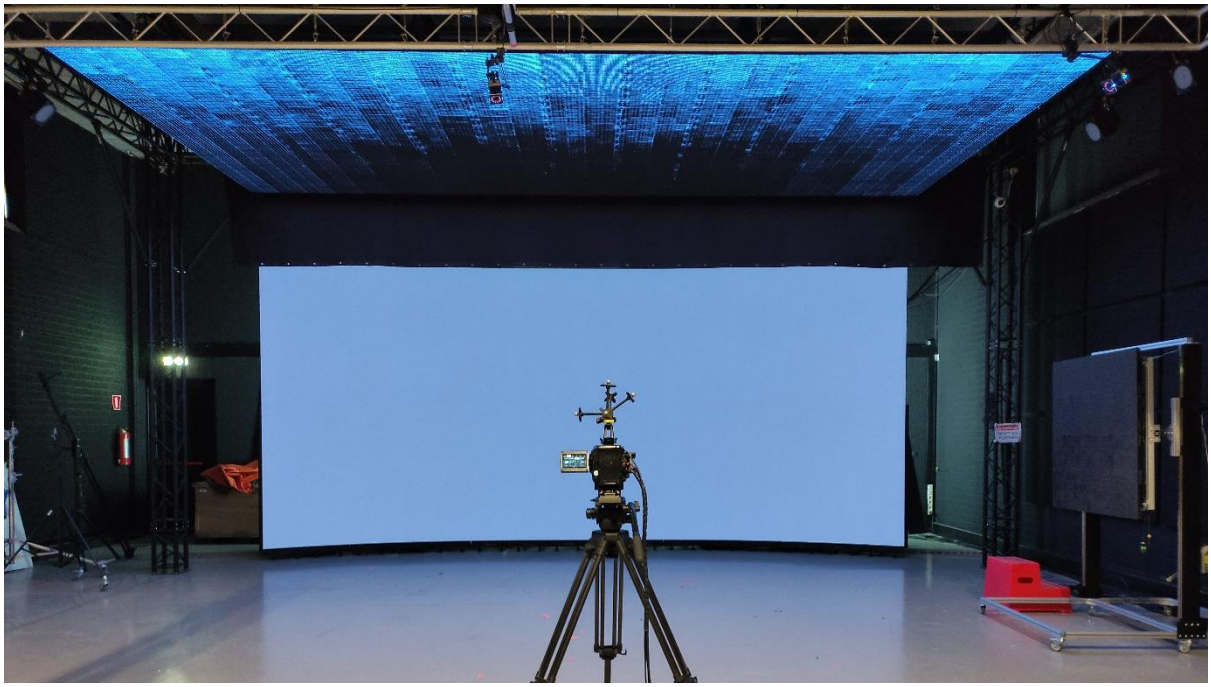
In this section of the literature the research parameters for this study are identified. The Virtual Production resources available and practises conducted at Breda University of applied sciences are explained, as well as the involvement and experience of the author in Virtual Production. Moreover, a selection of three movies is listed by the author, in which information on how they were filmed was collected and explored in detail. Furthermore, challenges on the production of these movies were identified and highlighted, which allowed the author to argue how they could have benefitted from utilising Virtual Production.

2.3.1 Breda University of applied sciences XR stage

Breda University of applied sciences, BUas (www.buas.nl), agreed to explore Virtual Production with the collaboration of Cradle (www.cradle.buas.nl), their Research and Development team. An LED volume was installed for educational and research purposes in what they called the Extended Reality stage, or XR stage, see Figure 5. The dimensions of the main volume are eight meters wide and three and a half meters tall with a pixel pitch of 2.6 millimetres. Similarly, a secondary four by eight-meter volume suspends from the ceiling parallel to the ground with a pixel pitch of 5 millimetres. As every individual LED is one pixel, the pixel pitch number indicates the distance between the LEDs. In short, the lower the pixel pitch number, the closer the LEDs are to each other, thus higher the resolution the LED volume will display.

Figure 5

XR stage at Breda University of applied sciences



Note. LED volumes of the XR stage at Breda University of applied sciences.

The purpose of the secondary volume suspended from the ceiling is not meant to be captured in-camera, except to provide the physical set with additional lighting and reflections from the contents displayed on the volumes during filming. Hence why its pixel pitch number is higher than the main volume since there is no need to have high quality imagery display on it.

Since the installation of the XR stage, a variety of projects and Virtual Production short films have been developed with media and games students, externals, and interns from Cradle. The author of this study had the opportunity to work on several Virtual Production projects adopting various different roles as part of the learning experience during their internship phase at Cradle. Some examples include, Vessel, 2022, Vessel 2, 2023, Greenhouse Insanity, 2023, and other internal and smaller-scale productions. Collaborations with Erasmus+ (https://erasmus-plus.ec.europa.eu) and the Virtual Production Studio Network, VPSN, (www.vpstudionetwork.com) have been developing workshops and material such as the Virtual Productions Knowledge Base (Santos et al., 2023) for various universities around Europe. Additionally, an annual Virtual Production Gathering (www.vpgathering.com) is hosted at BUas where industry experts are invited to share their knowledge, and network

with other Virtual Production related experts, production companies, partners, providers, and others.

The XR stage at BUas is mainly for educational purposes and research into the innovative field of Virtual Production. Because it falls into the education facilities and budgets, there are limited resources regarding filming equipment and dimensions of the stage and LED volumes. Moreover, there are time restrictions for its use since it was agreed on by the institution that it would be a public space for students and available for other types of projects unrelated to Virtual Production.

The learning points of working on a small-scale stage and limited resources are of high value for training the fundamentals of this innovative workflow. There are elements, however, that cannot be accomplished in comparison to large scale productions. Nevertheless, knowing the principles is useful to be able to expand to a larger scale. Therefore, in this research a selection of three movies was made, where in each movie a handful of short scenes were selected to reproduce in a small-scale fashion: Arrival, 2016, Pirates of The Caribbean: Dead Man's Chest, 2006, and All Quiet on the Western Front, 2021.

2.3.2 Experimental Reproductions

Bennett (2020) conducted a qualitative study about the immersion of actors through the use of Virtual Production tools. This study carried out a series of experimental productions for the facilitation of the data collection. The work of Bennett (2020) inspired the adoption of a similar terminology for the methodology phase of this paper. The reason being that a series of experimental productions were also conducted for this study, yet, with some differences to the ones from Bennett (2020).

For the purpose of this study, the experimental productions were called experimental reproductions. The productions were an experimental aspect in this study to facilitate the research with data collection, not a professional final product by themselves. They were called reproductions because their purpose was to recreate an already existing scene, hence reproducing those scenes.

2.3.2.1 Arrival

Directed by Denis Villeneuve, Arrival, 2016, is an emotionally arresting, visually inventive science fiction movie based on the award-winning Story of Your Life by Ted Chiang. A total of eight weeks of pre-production time took place for the preparation of the film, with a principal photography phase of 56 days (Hogg, 2021b). Followed by an eight-month period of post-production where the editing, colour grading, sound design, and VFX took place (Elwyn,

2017). A total of $47 million dollars was spent on the budget for this production according to Giardina (2016).

> In Arrival, the lone sci-fi film in contention for the Best Picture Oscar, linguist Louise (Amy Adams) meets with the mysterious aliens in a gigantic room inside their ship, where a glowing, semi-translucent wall conceals the extraterrestrials. That striking contrast between the bright wall and the otherwise dark interior was the creation of production designer Patrice Vermette. (Grierson, 2017)

In these particular scenes throughout the movie, the protagonist enters the alien spaceships alongside with a physicist and an elite team of investigators. They meet and interact with the aliens in an ominous meeting room to try to decipher the logograms the aliens write into determine the purpose of their visit to earth, see Figure 6.

Figure 6

Arrival, 2016

Note: Louise stands in the ominous meeting room in front of the aliens. From *Arrival*, by Denis Villeneuve (Director), 2016, Paramount Pictures.

Production designer Patrice Vermette found inspiration for the meeting room of the alien spaceship in an exhibition of visual artist James Turrell. The artwork of Turrell mostly

involves holograms and coloured lights, sometimes bathing whole rooms in a single colour projected from one wall, says Vermette (Grierson, 2017).

Vermette explains how he wanted to convey the simplicity and sensorial experience of the meeting room. The large screen in the room was meant as an element to unite the world of Luise. According to Vermette “That room, which they called in the script 'the interview room,' is a classroom” (Grierson, 2017). The white screen sustains a repeated motif as a narrative element that supports the theme of the story throughout the movie. There is a wide glass windowpane in the house belonging to Louise that is shown numerous times before she steps foot in the alien ship, hinting towards how the white screen will look like in the ship (Kuegler, 2023).

According to Hogg (2021b), a 150-foot tunnel with a ceiling and four real walls was built to shoot the interior of the ship, see Figure 7. The construction came with its limitations and restrictions which required the Director of Photography, Bradford Young, to become more inventive. The main challenge Young faced was to stay true to form on how the set was designed by Vermette. An additional requirement was to create a third level of singularity by allowing the light source of the ship to be precise however not to overthink it. The use of soft light was key “It made for a more meditative almost binary space where we have spectacular scale with these deep rich black walls and a beautiful soft light source that the actors could interact with” (Hogg, 2021b).

Figure 7

Arrival, 2016, behind the scenes

Note. Behind the scenes in the ominous meeting room set (designed by Patrice Vermette). From *Arrival*, by Denis Villeneuve (Director), 2016, Paramount Pictures (https://www.youtube.com/watch?v=KrCpOK02osU). Copyright 2017 by Paramount Movies.

The visual look of the spaceships was meant to project the idea that the extraterrestrials came from a strange world although also a very attracting one. In hopes for a fresh design, Vermette thought of using sediment rock as texture for the ships, which would represent the wisdom and history, as well as the purity of that civilisation. “If you compare the interior of the ship to the interior of the white tents for the military camped out near the spacecraft, inside those tents is chaos, but inside the ship there is a feeling of peacefulness” (Giardina, 2016).

It is worth highlighting the scenes where the team of investigators enter the spaceship into the ominous meeting room where they encounter face-to-face with the aliens. The desire to carry out experimental reproductions for these scenes with Virtual Production tools arose after concluding that the setting of these shots could be ideal to capture on an LED volume. The primary reasons would be that the screens where the extraterrestrials are standing behind are the similar shape of the actual LED volume and in an ideal position from the main characters to shoot from. There are no camera movements which makes for a simpler execution. The camera framings range from medium shots to medium full shots, which are great options for Virtual Production as they do not add extra complications trying to set dress the floor, walls, or ceiling, and blending it with the content displayed on the LED volume.

Additionally, Vermette highlights the key source light being a soft white light coming from the alien screens (Hogg, 2021b), which works great with the soft light that the volume emits.

There are also limitations worthy to mention regarding this method of filmmaking. For instance, the possibility to shoot wide shots where the floor and ceiling are visible in camera are restricted due to the physical limitations of the eight-meter wide by three-and-a-half-meter tall LED volume at the BUas facilities available to the researcher. Moreover, the VFX animations and fidelity of the extraterrestrials would be challenging to mimic when comparing the abilities of one single game development student creating the 3D assets, with the professional CGI and VFX departments that worked on Arrival.

2.3.2.2 Pirates of the Caribbean: Dead Man's Chest

Directed by Gore Verbinski, Pirates of the Caribbean: Dead Man's Chest is an American fantasy swashbuckler film released in 2006. It is the second instalment of the Pirates of the Caribbean film series. Principal photography took around seven months in multiple filming locations such as Palos Verdes, Saint Vincent and the Grenadines, Dominica, and The Bahamas, as well as in sets constructed at Walt Disney Studios (Atlantis International, 2007a).

The total production costs for the movie are estimated to be $225 million dollars (IMDb, 2006) and as for the Worldwide Box Office, Pirates of the Caribbean: Dead Man's Chest made a total of earnings of $1.06 billion dollars (Madaan, 2023), which ranks this movie amongst the top 50 highest-grossing movies in history (Box Office Mojo, n.d.).

The nature of this movie presented massive challenges due to the remote locations it had to be filmed in, as well as the large number of crew and equipment that had to be brought in those locations. Verbinski and production designer Rick Heinrichs decided that Dominica, an island in the Eastern Caribbean Sea would be the main location for two major settings in the movie. Additionally, the unpredictable weather of the island presented many challenges (Atlantis International, 2007c).

Heinrichs and construction coordinator Greg Gallas mention that the island had poor road conditions, making it difficult to travel across. The logistics of the production were an immense challenge for the reason that supplies were so limited and had to be imported from other countries in the Caribbean and South America. According to Callas "we had to bring in everything, like an entire hardware store: every nail, piece of wood, sack of cement and plaster, gallon of paint" (Atlantis International, 2007c).

Seeing how many physical challenges the filming of this production presented, it led to the desire of exploring the possibilities of choosing certain scenes to recreate in Virtual Production.

For this research, a particular scene from the movie was chosen to execute various experimental reproductions in the methodology phase. The scene unfolds in a shallow river, where the main characters are passing through on a small wooden boat, see Figure 8. This scene was filmed in the Indian River, in Portsmouth, on the northeast of Dominica. The construction department built wooden shacks that would be seen in the back of the set. Callas explains “We prefabricated those shacks in our warehouse, disassembled them, put them on these little boats, took them out to the locations and set them up in a couple of days” (Atlantis International, 2007a).

Figure 8

Pirates of the Caribbean: Dead Man’s Chest, 2006

Note. Joshamee Gibbs (Kevin McNally) and William Turner (Orlando Bloom) travel upriver on a small boat. From *Pirates of the Caribbean: Dead Man’s Chest,* by G. Verbinski (Director), 2006, Walt Disney Pictures.

Additionally, Callas mentions that because of the ecological sensitivity of the river the cast and equipment had to be sent upriver in manually rowed boats, or electric motors only which took up to an hour to arrive at the filming area. Once more, the stormy weather also interrupted the filming of these scenes (Atlantis International, 2007b).

The main motive to capture this particular scene with ICVFX was due to the aforementioned production challenges that the team had to go through. Exploring the extend to with one could reproduce such a scene inside a studio in a controlled environment, with no travel expenses, no unpredictable weather conditions, less resources, and budget is what drove the researcher to choose this scene.

However, the restrictions of approaching this type of filmmaking are commonly known in the Virtual Production industry. The original scene was filmed in broad daylight, which is difficult to produce with studio lighting. The sequence includes a real river, which contains water that would be a complex challenge to set up in a Virtual Production stage, where damaging the LED volume and filming equipment would be a risk factor. The continuous movement of the boat has the effect of moving, or dynamic shadows on the characters due to the overhanging trees in the scene, which could add another challenge to the execution. Additionally, the camera follows the boat as its moving through the water, which adds an extra layer of difficulty as the physical dimensions of the LED volume available to the researcher would not allow for the camera to travel in such a movement.

2.3.2.3 All Quiet on the Western Front

Directed by Edward Berger, All Quiet on the Western Front, 2022, is a Netflix adaptation of the anti-war novel of Erich Maria Remarque, known as “still the most widely read piece of German literature worldwide, with up to 40 million copies sold since it first came out in 1929” (Schultze, 2023). The movie depicts the terrifying experiences, reality, and distress of a young German soldier on the western front during WWI (Ramachandran, 2021). The film was fully developed by a German language team in charge behind the writing, directing, and acting (Schuetze, 2022).

Principal photography took around 55 days, with a total production cost of $20 million dollars (Rodek, 2022). Filming was done in the Czech Republic where the crew had to recreate the destroyed hinterland in France, says production designer Christian M. Goldbeck. The crew chose their main filming location after they found a military training area and airfield 45 minutes north of Prague, says producer Malte Grunert. Berger adds that the construction team had to build an entire battlefield with its trenches the size of ten soccer fields, see Figure 9. On top of that, the construction team hat to dig up to 250 linear meters of tunnels for the action and scenes filmed inside of the trenches, says Goldbeck (Becker, 2022).

Figure 9

Behind the Scenes, All Quiet on the Western Front, 2022

Note. Film set construction of the battlefield and trenches at a military training area and airfield near Prague, Czech Republic. From *Anatomy of a War Film,* by T. Schultze, 2023. Netflix Queue. (https://netflixqueue.com/all-quiet-on-the-western-front-behind-the-scenes).

The earth in the filming area in the Czech Republic was too brown, as in Berlin. According to Berger “It suggests heat and dessert instead of cold and ice” (Schultze, 2023). This meant that the crew had to bring in additional dark soil to achieve the black and burned look, with added bomb craters partially filled with water to accentuate the effect (Schultze, 2023).

The amount of complexity, preparation, and resources that were spent on this movie is no doubt what made it a great success. However, it sparked the desire to explore what the capabilities were of recreating some of its scenes by replacing the massive battlefield with a virtually displayed version on an LED volume to be captured with ICVFX. The idea behind this process was to learn if capturing a close resemblance using Virtual Production tools would be possible, and to what extent it would resemble to the original shots. It is worth mentioning that choosing this process limits the number of options regarding camera angles, movements, and framings, since it is imperative to stay inside the physical constraints of the eight-meter wide by three-and-a-half-meter tall LED volume available to the researcher.

For this research the specific scene that was chosen to adopt in various experimental reproductions was a night scene where the two main characters are hiding behind a wall made of sandbags, taking turns to night guard their post. A wide shot shows the extend of the large battlefield in the background, while a flare gun in the far back falls from the sky and lights up the entire environment, see Figure 10.

Figure 10

All Quiet on the Western Front, 2022

Note. Wide shot of a nighttime scene. From *All Quiet on the Western Front,* by E. Berger (Director), 2022, Amusement Park.

Following this wide shot, the camera cuts to a closer medium shot where the two characters are seen in more detail. They suddenly hear a sound nearby, which makes one of them to creep up and peek their head over the sandbags, suspecting that they might suffer an ambush as he takes his gun and points it towards the front, see Figure 11.

Figure 11

All Quiet on the Western Front, 2022

Note. medium shot of a nighttime scene. From *All Quiet on the Western Front,* by E. Berger (Director), 2022, Amusement Park.

This sequence made up of the combination of the two shots could be argued to be ideal to capture using Virtual Production. The main reasons being that the camera movements are completely static, or very minimal, the background elements are out of the depth of field of the camera, and there are no major complex elements unfolding in camera besides the flare gun, which could be argued to add additional challenges regarding the visual effects making, and the lighting it casts on the scene and the subjects. Nevertheless, the possibility to capture a close looking final picture without the need to construct the large battlefield, or the added practical effects such as the fires, or the flare gun led the researcher to select this scene.

2.4 Conclusion

This chapter highlighted the existing literature and concepts confining the study by exploring technologies and procedures that have been established in contemporary Virtual Production. Additionally, this chapter addressed the research parameters that allowed the completion of this study.

The overall agreements according to the sources in the Virtual Production industry state that this workflow allows productions to be simplified, more cost-effective, environmentally friendly, and flexible. Filming in a controlled environment eliminates unpredictable weather and travel expenses, while maintaining the quality of final image outputs. This enables small-

scale productions with less resources to develop similar final products that of blockbusters (Fair, 2023; Kadner, 2019; Priadko & Sirenko, 2021).

2.4.1 Hypotheses of the Study

Exploring Virtual Production in an academic setting was possible at BUas as mentioned in Section 2.3.1. The circumstances of this research were optimal to explore Virtual Production in a small-scale environment. Therefore, the following hypotheses were developed to answer the research question:

H1: Virtual Production, utilising LED volumes within constricted resources, yields final imagery comparable to those in feature-length films.

H2: Virtual Production, utilising LED volumes within constricted resources, is more cost-effective than traditional filmmaking without sacrificing final image quality.

H3: Virtual Production, utilising LED volumes within constricted resources, is more time-effective than traditional filmmaking without sacrificing final image quality.

These hypotheses were based on Kadner (2019), Priadko & Sirenko (2021), and Fair (2023). To investigate the truth of these hypotheses, a survey comparing the experimental reproductions, against the original film scenes mentioned in Section 2.3.2, was carried out in the Methodology phase.

3. Methodology

3.1 Introduction

This chapter outlines the research design adopted for this study to achieve the results and objectives proposed in Section 2.3.2 that will facilitate the data collection. Also, this chapter explains the methods used to carry out the research such as experimental reproductions to collect the data necessary to discuss the level of the proposed achievements. This chapter also justifies the approaches for collecting data during the production phases, and the methodology used to analyse the data once the productions were finalised.

3.2 Research Design

This study carried out a quantitative approach survey research to collect data with quantifiable variables. According to Matthews and Ross (2010) “quantitative research methods are primarily concerned with gathering and working with data that is structured and can be represented numerically (…) and data is collected that can be statistically analysed” (pp.141-142). Survey research is defined as “the collection of information from a sample of individuals through their responses to questions" (Check & Schutt, 2012, p. 160).

A quantitative methodology was chosen to measure the level of resemblance of the conducted experimental reproductions to the original scenes by analysing quantifiable variables. The data collection for this chapter adopted a similar approach to the aforementioned study from Bayo-Moriones et al. (2018) were they followed the ranking system method of Myers (1999) as inspiration for data collection by leading the respondents of the questionnaire to make trade-offs by ranking a list of characteristics based on their opinions. Furthermore, the timeframe and sample size of this research best suited a quantitative approach. Due to the need of acquiring results in a quicker manner and the need for a large sample group, which would have not been possible within a qualitative approach.

3.3 Methods

The following methods were adopted for this study to explore Virtual Production tools and the visual authenticity this procedure can provide. Additionally, the approach for the methodology was validated by the researcher and the company supervisors after concluding that the previous experience of the researcher in Virtual Production projects mentioned in Section 2.3.1 was of sufficient level to carry out the experimental reproductions for the methodology. Moreover, the development of the experimental reproductions confirmed that the research was valid and relevant for the industry.

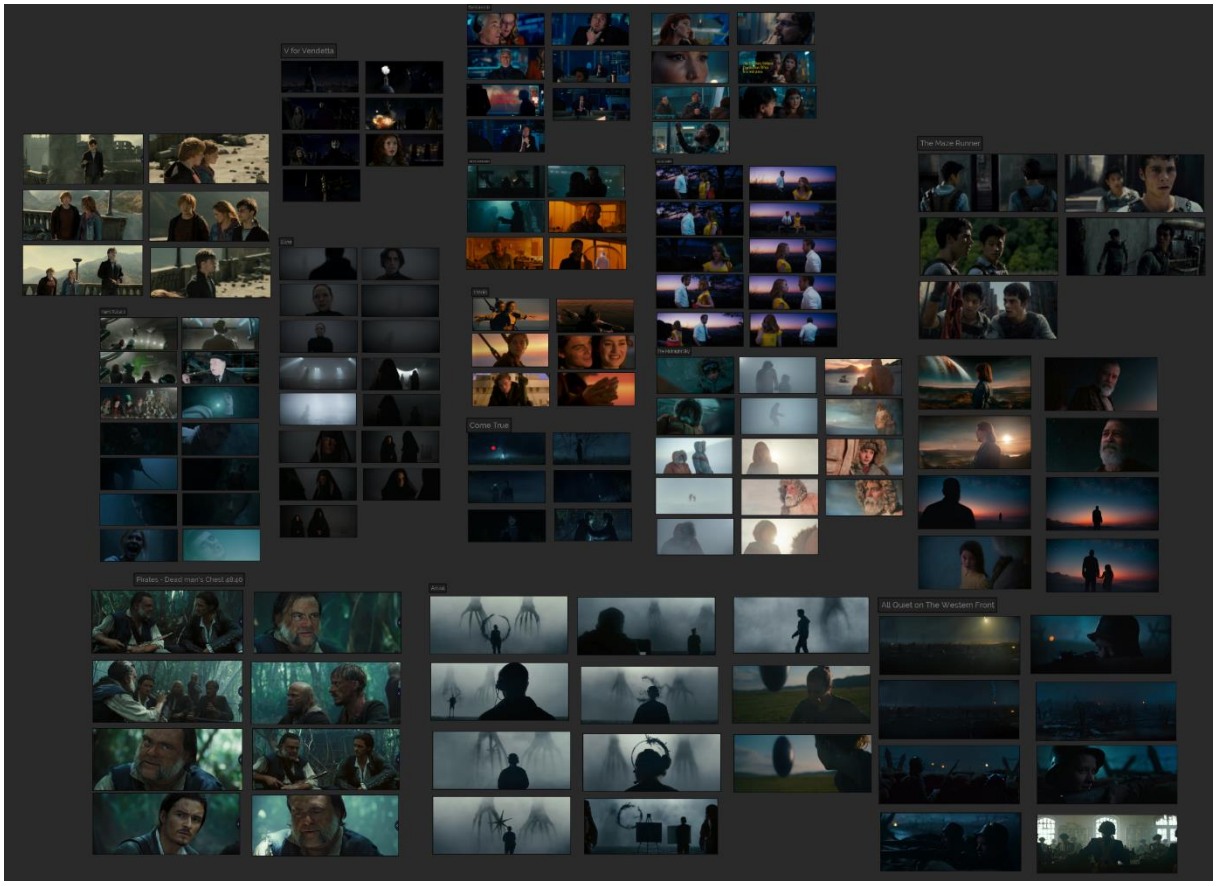
3.3.1 Experimental Reproductions

This study conducted a series of experimental reproductions previously explained in Section 2.3.2 using the aforementioned Virtual Production tools and procedures cited in the literature review. Ensuring a realistic approach that suited this research was crucial to decide the movie scenes to be adopted through these experimental reproductions. Therefore, a review to determine which type of shots are most beneficial to film with Virtual Production took place based on the findings of the literature review. On top of that, the physical dimensions of the LED volume employed for this study, time at hand, availability of the actors, and the scope of this research further influenced in the decision making. Bearing these factors in mind, a scouting phase for potential movie scenes, see Figure 12, commenced to finalise a selection of three existing movie scenes that had to meet certain criteria within the following categories: *composition, framing, production type, level of VFX,* and *variety*.

The *composition* of the scenes included at least one main subject in the foreground positioned within a certain distance in relation to the background environment. The *framing* of the shots were medium full shots, medium shots, or close up shots. The *production type* was either done on location or in a film studio where a film set had to be constructed and no green screen, blue screen, or Virtual Production was utilised. The *level of VFX* or any form of VFX or CGI added in post-production, or practical VFX captured in-camera, was of a certain level of simplicity. Lastly, the final selection had to include a sufficient level of *variety* regarding the genre, type of setting, type of lighting, and colour scheme. The finalised selection had to meet the above-mentioned criteria for the purpose of the scope of this study and limitations to the researcher, explained in more detail in Section 5.2.

Figure 12

Exploration phase for potential movies



Note. Graphic showing all potential movies that were considered by the author for the experimental reproductions.

As soon as the author confirmed the final selection, the planning and preparation was done to carry out the experimental reproductions. A series of references, the original footage of the selected film scenes, and instructions were given to the 3D artist to recreate the original backgrounds in a computer graphics game engine. The software utilised were Unreal Engine (version 5.3), ZBrush (version 2023.2), Autodesk Maya (version 2025), Houdini (version 20), and Blender (version 4.1). The virtual 3D environments would subsequently be displayed on the LED volume during filming.

Once the virtual environment created for the experimental reproductions had its main components in place, a series of testing days at the XR stage at BUas were conducted with the LED volume to work out the positioning of the camera, positioning of the actors, and lighting parameters, as well as making the final adjustments on the virtual scene.

For the first experimental reproduction, Arrival, three days for testing and two days for filming were planned. Four scenes from the movie were chosen to be reproduced, the entire scenes can be found in Appendix A: A1, A2, A3, and A4. For the second experimental reproduction, Pirates of the Caribbean: Dead Man's Chest, four days for testing were carried out with the LED volume, and two days for filming were planned. One scene from the movie composed of two shots was selected to reproduce. The entire scenes can be found in Appendix A: A5, and A6. For the third and final experimental reproduction, All Quiet on the Western Front, three testing days with the LED volume proceeded with one filming day. One scene was selected from this movie which contained two separate shots. The entire scenes can be found in Appendix A: A7, and A8. The availability constrains of the XR stage was the main deciding factor to how many testing and filming days were allocated for each film.

The completion of the preparation and testing phase led to the production phase. The production phase comprised of a succession of filming days, with separate dates for each movie and its chosen scenes. A total of three filming days took place, sparing one of the extra planned filming days in some cases. The production phase was designed to be carried out by a small team of collaborators assisting during the filming days. However, most of the preparations during the pre-production phase was done by the author and the 3D artist. The filming days consisted of a small internal crew formed by the author who adopted the role of director, producer, camera operator, lighting technician, and set designer, a 3D artist fourth year student from the Creative Media and Game Technologies at BUas in charge of the content displayed on the LED volumes and adjusting the virtual environments, a member in charge of taking behind the scenes footage, and the actors that were required for the different scenes, which were internal co-workers from the commissioner company, Cradle.

The filming days were comprised of a series of steps which included the setup and calibration of the camera tracking system Vicon Motion Capture Systems, the set dressing of the filming area, the setup of the displayed content on the LED volumes, the positioning of the lighting, the setup of the camera, and the costume and make-up arrangements. Once these steps were completed and running properly, a large computer monitor displaying the original scenes was positioned where the actors could see from their acting positions to facilitate their performances and rehearse the movements and timings of the original shots. Once the rehearsals were close to the desired outcome, the recording of the takes took place. The takes were recorded in Blackmagic RAW format in 4K resolution on a Blackmagic Ursa Mini Pro 12K, and a selection of best takes was made after each filming day to facilitate the post-production process.

The completion of the production phase led to the post-production phase in which the author adopted the role of video editor and colourist. This phase began with the importation of the footage into the editing software. Once the best and final take was selected for each experimental reproduction, the footage went through the editing and colour grading process. The decision to film in Blackmagic RAW video format was made for the reason that these files contain all the colour information and image detail captured by the sensor, which means that there is no compression or loss of information. Consequently, colour grading is more easily customisable to achieve the desired final outcome. The software utilised for the editing and colour grading during this phase was Davinci Resolve Studio (version 18.6). Furthermore, the behind-the-scenes footage captured during the experimental reproductions was meant to provide complementary material to showcase the link between the theory and practice in this study. Chapter 5.2 explains in detail the challenges and problems that were faced during the pre-production, production, and post-production phases of the experimental reproductions.

3.3.2 Population and Sampling method

This study focuses on the achievability of industry standard quality filmmaking using Virtual Production as an alternative production tool. Therefore, the unit of analysis is the average film consumer. There is no precise global statistic on the percentage of the world population that consume movies. Additionally, the percentages likely vary depending on factors such as region, age, socioeconomic status, access to cinema and streaming platforms, or cultural preferences. Nevertheless, movies are a significant form of entertainment around the world reaching millions of individuals. According to Elad (2024), the annual revenue of the global film industry was 77$ billion dollars in 2022, and over 50 million tickets were sold worldwide in the year 2023. That being so, it is safe to say that a substantial portion of the global population are film consumers in some form.

When deciding to consider sampling for this research, the author followed Saunders et al. (2007, p. 227) guidelines and determined that there was no need for sampling since the film industry englobes and reaches the entire population, meaning that the data could be collected from the entire population. For this study, the data collection required a minimum of 60 respondents. The survey collected 98 responses. However, a portion had to be discarded after an anomaly in the data collection. Furthermore, two participants opted to cancel. In the end, a total of 56 valid responses were able to collect.

3.3.3 Instrument of Data Collection

For the purpose of data collection, quantifiable data was compared with AB testing in a control experiment. A survey, see Appendix C, was developed containing two blocks of

questions, one for group A, and one for group B. Both groups contained the same questions, however, with unalike visual content for each of the groups. Group A was shown the unedited scenes of the original movies, with the audio removed. For simplicity and the scope of this study, the author opted to exclude the audio as a factor for data collection and to steer the focus of the research on the visual parameters instead. Group B was shown the same scenes, instead, with the replacement of the shots from the footage developed during the experimental reproductions. The questionnaire was set up in a way that would display either group A or group B questions to each participant with a randomiser to ensure an equal number of responses from both groups, see Appendix C.

The first part of the survey adopted a similar structure to Bayo-Moriones et al. (2018), which utilised Myers (1999) methodology of asking the participants to rank a list of items in order of importance. This was to avoid responses to clump up to the upper end of the rating scale. The items that had to be rated were *authenticity, realism and believability*, *special effects*, and *visual effects*.

The second part of the survey included a set of seven questions, each displaying one different movie scene, previously listed in Section 3.3.1. To avoid question order bias from respondents, the order of the questions was randomised. For group A, the original scenes with no alterations were shown, see Appendix D. For group B, the original scenes were replaced with the material developed during the experimental reproductions, see Appendix E. For each question, respondents were asked to indicate their agreement or disagreement on a 5-point Likert scale, 1-strongly disagree; 5-strongly agree, with a number of statements regarding *authenticity*, *realism and believability*, and *type of production*.

To determine the level of *authenticity*, the author based the questions on the measurements conducted by Radbourne et al. (2009). To measure the *authenticity* of the material that is being offered, the survey included the following statements for each question: The visuals are up to technical standards; The visuals are made by the filmmakers that appear on the credits of the production. To measure the emotional perception of *authenticity*, which explores the *realism and believability* aspects, the following statement was included in the survey: The visuals are of such quality that I believe what is happening is real.

To determine the perception of the audience regarding the *type of production*, the following statements were made: This scene was filmed on a real physical location; This scene was filmed inside of a studio. Based on the results of these two statements the author could determine whether the audience believed the scenes were filmed on location with practical effects, or instead filmed in a studio with the use of visual effects added subsequently - what

the audience would most likely presume to be green screen techniques. By doing so, the author could attest to the level of image quality that Virtual Production can offer.

3.3.4 Procedures for Data Collection

In an attempt to gather responses from as much of the global population, multiple methods of distribution for the survey were applied. The first method consisted of posting a link to the survey via the social media platform LinkedIn, both on the personal account of the author and on the account of the commissioner company. The second method utilised was to approach participants in person on the BUas campus grounds to ask students from various academies to participate in the survey. Additionally, a quick response, QR, code linking to the survey was printed out and placed around the educational facilities. Other methods were used such as distributing the link of the survey through direct messages in text chats and group chats from friends and family of the author. The entire duration of the data collection took around two weeks.

3.3.5 Procedures for Data Analysis

The data analysed was processed through statistics software SPSS (version 27). For the purpose of measuring the quality perception from group A and group B the data was analysed through various tests.

The first test evaluated the reliability and validity of the results by conducting a normality test and meeting the normality assumptions. A Kolmogorov-Smirnov (Van Den Berg, n.d. -a) and Shapiro-Wilk (Van Den Berg, n.d. -b) tests were conducted for part one of the survey. Both visual and text analysis was investigated to determine if the data was normally distributed.

After determining that the data was not normally distributed, a nonparametric test was done for each of the three main outlined concepts: Authenticity, realism and believability, and type of production. The Mann-Whitney U-Test (DATAtab Team, 2024) was carried to determine if there was a difference between the two samples. The rank sums of the two samples were used rather than the means as in the t-Test (JMP Statistical Discovery, n.d.) for independent samples. This test served to answer the null hypothesis and the alternative hypothesis.

Null Hypothesis: In the two samples, the rank sums do not differ significantly.

Alternative Hypothesis: In the two samples, the rank sums do differ significantly.

By carrying out a Mann-Whitney U-Test, the data could be analysed based on which hypothesis it confirmed. If the Null Hypothesis was not rejected, the difference was not statistically significant between both groups, meaning that group A and group B perceived the visual quality similarly. Therefore, it could be argued that the experimental reproductions

did not have a significant difference from their original scenes, confirming the hypothesis of the study **H1:** Virtual Production, utilising LED volumes within constricted resources, yields final imagery comparable to those in feature-length films. Furthermore, if **H1** was confirmed, the rest of the hypotheses would not be rejected: **H2**: Virtual Production, utilising LED volumes within constricted resources, is more cost-effective than traditional filmmaking without sacrificing final image quality; **H3**: Virtual Production, utilising LED volumes within constricted resources, is more time-effective than traditional filmmaking without sacrificing final image quality.

If the Alternative Hypothesis was not rejected, the difference was statistically significant between both groups, meaning there was a dissimilarity in visual quality for group A and group B. Thus, it could be argued that the experimental reproductions did have a significant difference from their original scenes, thus rejecting **H1**, **H2**, and **H3.**

3.3.6 Ethical Considerations

This study was considered a small risk research report in which there were no major foreseeable discomforts or harm to participants. To ensure the comfort of researchers and participants that contributed to this study, several considerations were made. These considerations were made up of two parts, the first part taking place in the development phase of the experimental reproductions, and the second part in the posterior collection of data through survey participants.

The considerations during the productions included ensuring the safety and comfort of the actors during filming, planning the filming sessions according to the availability of the actors, making sure that all communication and documents consisted of English language to guarantee the inclusion of all collaborators in the process, and attribution for creative contribution to a production.

To ensure a good research practice, this study followed the Association of Social Anthropologists of the UK and the Commonwealth (1999) guidelines for the data collection process. Responses from the survey were collected anonymously to protect the rights and confidentiality of the participants. Additionally, a disclaimer before starting the survey was included regarding the inclusion of a particular movie in the survey that is R-rated for strong bloody war violence and grisly images. The disclaimer allowed the participants to opt out of the survey before starting in case they felt uncomfortable.

4. Results

The survey distributed for this study consisted of a total of 98 respondents. As a control experiment, an equal number of responses was aimed to collect for each sample group. However, an anomaly in the data collection made a portion of the responses to be discarded. Furthermore, a total of two participants opted to cancel. Therefore, a total of 56 valid responses were recorded, see Table 1.

Table 1

Total number of valid survey responses

Valid	Proceed with survey	56
	Cancel	2
	Total	58

A normality test for the first part of the survey, question: When you look at the visual quality of a film, which of the following statements are most important to you? Was calculated for both groups, see Table 2. The results of the normality test showed that most of the data was not normally distributed on either group.

Table 2

Kolmogorov-Smirnov and Shapiro-Wilk normality tests on both groups

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Group		Statistic	df	Sig.	Statistic	df	Sig.
Group A	The visuals are up to technical standards.	.344	31	.000	.808	31	.000
	The visuals seem to be made by the filmmakers that appear on the credits of the production.	.211	31	.001	.864	31	.001
	The visuals are of such quality that I believe what is happening is real.	.281	31	.000	.832	31	.000
	The quality of the special effects, like real explosions filmed on set.	.262	31	.000	.852	31	.001
	The quality of the visual effects, like computer-generated imagery.	.224	31	.000	.858	31	.001
	When a film is captured on a real physical location rather than in a studio.	.218	31	.001	.878	31	.002
Group B	The visuals are up to technical standards.	.263	25	.000	.873	25	.005
	The visuals seem to be made by the filmmakers that appear on the credits of the production.	.156	25	.118	.901	25	.019
	The visuals are of such quality that I believe what is happening is real.	.269	25	.000	.796	25	.000
	The quality of the special effects, like real explosions filmed on set.	.211	25	.006	.887	25	.010
	The quality of the visual effects, like computer-generated imagery.	.303	25	.000	.835	25	.001
	When a film is captured on a real physical location rather than in a studio.	.196	25	.014	.888	25	.010

Note. Normality tests for the question: When you look at the visual quality of a film, which of the following statements are most important to you?

A non-parametric test was conducted to determine whether there was a difference between the two sample groups. The Mann-Whitney U-Test was conducted to calculate the rank sum difference between both groups for the question: When you look at the visual quality of a film, which of the following statements are most important to you?

Table 3

Rank sum between both groups

	Group	N	Mean Rank	Sum of Ranks
The visuals are up to technical standards.	A	31	33.02	1023.50
	B	25	22.90	572.50
The visuals seem to be made by the filmmakers that appear on the credits of the production.	A	31	32.19	998.00
	B	25	23.92	598.00
The visuals are of such quality that I believe what is happening is real.	A	31	26.97	836.00
	B	25	30.40	760.00
The quality of the special effects, like real explosions filmed on set.	A	31	30.34	940.50
	B	25	26.22	655.50
The quality of the visual effects, like computer-generated imagery.	A	31	28.82	893.50
	B	25	28.10	702.50
When a film is captured on a real physical location rather than in a studio.	A	31	26.27	814.50
	B	25	31.26	781.50

Note. The sum of ranks of both groups for the question: When you look at the visual quality of a film, which of the following statements are most important to you?

Table 4

Mann-Whitney U-Test

	The visuals are up to technical standards.	The visuals seem to be made by the filmmakers that appear on the credits of the production.	The visuals are of such quality that I believe what is happening is real.	The quality of the special effects, like real explosions filmed on set.	The quality of the visual effects, like computer-generated imagery.	When a film is captured on a real physical location rather than in a studio.
Mann-Whitney U	247.500	273.000	340.000	330.500	377.500	318.500
Z	-2.489	-1.933	-.835	-.999	-.176	-1.166
Asymp. Sig. (2-tailed)	.013	.053	.404	.318	.860	.244

Note. Mann-Whitney U-Test for the question: When you look at the visual quality of a film, which of the following statements are most important to you?

The significance, 2-tailed, was above the significance level of 0.05 for each statement except statement one, that was .013. A Mann-Whitney U-Test showed that the difference was not statistically significant between both groups for all statements except for: The visuals are up to technical standards. Therefore, the alternative cannot be rejected for the first statement, and the null hypothesis cannot be rejected for all other statements.

For the second part of the survey, each group had seven questions with five statements each. These statements were categorised into three main concepts previously outlined in the literature: Authenticity, realism and believability, and type of production.

4.1 Authenticity

A Mann-Whitney U-Test was carried out for all seven questions. The statements that measured authenticity were: The visuals are up to technical standards; The visuals are made by the filmmakers that appear on the credits of the production. The results were divided into their corresponding film scenes in the sections below.

4.1.1 Arrival

Questions Q1 to Q4 in the survey corresponded to the scenes from Arrival. The significance level, 2-tailed, was of .814 for Q1, .471 for Q2, .183 for Q3, and .009 for Q4. The values of Q1, Q2, and Q3 were above the significance level of 0.05, while the significance level of Q4 was below the significance of 0.05.

A Mann-Whitney U-Test showed that the difference for Q1, Q2, and Q3 was not statistically significant between both groups, except for Q4. Therefore, the null hypothesis cannot be rejected for Q1, Q2, and Q3. However, the alternative hypothesis cannot be rejected for Q4, see Table 5 and Table 6.

Table 5

Rank sum between both groups.

	Group	N	Mean Rank	Sum of Ranks
Q1 Authenticity	A	31	28.95	897.50
	B	25	27.94	698.50
Q2 Authenticity	A	31	29.87	926.00
	B	25	26.80	670.00
Q3 Authenticity	A	31	31.06	963.00
	B	25	25.32	633.00
Q4 Authenticity	A	31	33.55	1040.00
	B	25	22.24	556.00

Note. The sum of ranks of both groups measuring authenticity in the scenes from Arrival.

Table 6

Mann-Whitney U-Test

	Q1 Authenticity	Q2 Authenticity	Q3 Authenticity	Q4 Authenticity
Mann-Whitney U	373.500	345.000	308.000	231.000
Wilcoxon W	698.500	670.000	633.000	556.000
Z	-.235	-.720	-1.330	-2.619
Asymp. Sig. (2-tailed)	.814	.471	.183	.009

Note. Mann-Whitney U-Test for authenticity in the scenes from Arrival.

4.1.2 Pirates of the Caribbean: Dead Man's Chest

Questions Q5 and Q6 in the survey corresponded to the scenes from Pirates of the Caribbean: Dead Man's Chest. The significance level, 2-tailed, was of .002 for Q5, and .099 for Q6. In the one hand, the significance level of Q5 was below 0.05. On the other hand, the significance level of Q6 was above 0.05.

Therefore, the alternative hypothesis cannot be rejected for Q5, and the null hypothesis cannot be rejected for Q6, see Table 7 and Table 8.

Table 7

Rank sum between both groups.

	Group	N	Mean Rank	Sum of Ranks
Q5 Authenticity	A	31	34.37	1065.50
	B	25	21.22	530.50
Q6 Authenticity	A	31	31.66	981.50
	B	25	24.58	614.50

Note. The sum of ranks of both groups measuring authenticity in the scenes from Pirates of the Caribbean: Dead Man's Chest.

Table 8

Mann-Whitney U-Test

	Q5 Authenticity	Q6 Authenticity
Mann-Whitney U	205.500	289.500
Wilcoxon W	530.500	614.500
Z	-3.081	-1.650
Asymp. Sig. (2-tailed)	.002	.099

Note. Mann-Whitney U-Test for authenticity in the scenes from Pirates of the Caribbean: Dead Man's Chest.

4.1.3 All Quiet on the Western Front

Question Q7 in the survey corresponded to the scenes from All Quiet on the Western Front. The significance level, 2-tailed, was of .041 for Q7. The significance level of Q7 was below 0.05.

A Mann-Whitney U-Test showed there was a statistically significant difference between both groups. Therefore, the alternative hypothesis cannot be rejected for Q7, see Table 9 and Table 10.

Table 9

Rank sum between both groups

Ranks

	Group	N	Mean Rank	Sum of Ranks
Q7 Authenticity	A	31	32.37	1003.50
	B	25	23.70	592.50

Note. The sum of ranks of both groups measuring authenticity in the scenes from All Quiet on the Western Front.

Table 10

Mann-Whitney U-Test

	Q7 Authenticity
Mann-Whitney U	267.500
Wilcoxon W	592.500
Z	-2.042
Asymp. Sig. (2-tailed)	.041

Note. Mann-Whitney U-Test for authenticity in the scenes from All Quiet on the Western Front.

4.2 Realism and Believability

A Mann-Whitney U-Test was carried out for all seven questions. The statement that measured realism and believability was: The visuals are of such quality that I believe what is happening is real. The results were divided into their corresponding film scenes in the sections below.

4.2.1 Arrival

Questions Q1 to Q4 in the survey corresponded to the scenes from Arrival. The significance level, 2-tailed, was of .761 for Q1, .636 for Q2, .510 for Q3, and .987 for Q4. These values are above the significance level of 0.05.

A Mann-Whitney U-Test showed that the difference was not statistically significant between both groups. Therefore, the null hypothesis cannot be rejected, see Table 11 and Table 12.

Table 11

Rank sum between both groups

	Group	N	Mean Rank	Sum of Ranks
Q1 Realism and Believability	A	31	27.92	865.50
	B	25	29.22	730.50
Q2 Realism and Believability	A	31	27.60	855.50
	B	25	29.62	740.50
Q3 Realism and Believability	A	31	27.24	844.50
	B	25	30.06	751.50
Q4 Realism and Believability	A	31	28.47	882.50
	B	25	28.54	713.50

Note. The sum of ranks of both groups measuring realism and believability in the scenes from Arrival.

Table 12

Mann-Whitney U-Test

	Q1 Realism and Believability	Q2 Realism and Believability	Q3 Realism and Believability	Q4 Realism and Believability
Mann-Whitney U	369.500	359.500	348.500	386.500
Wilcoxon W	865.500	855.500	844.500	882.500
Z	-.304	-.474	-.659	-.017
Asymp. Sig. (2-tailed)	.761	.636	.510	.987

Note. Mann-Whitney U-Test for realism and believability in the scenes from Arrival.

4.2.2 Pirates of the Caribbean: Dead Man's Chest

Questions Q5 and Q6 in the survey corresponded to the scenes from Pirates of the Caribbean: Dead Man's Chest. The significance level, 2-tailed, was of .021 for Q5, and of .097 for Q6. In the one hand, the significance level of Q5 was below 0.05. On the other hand, the significance level of Q6 was above 0.05.

Therefore, the alternative hypothesis cannot be rejected for Q5, and the null hypothesis cannot be rejected for Q6, see Table 13 and Table 14.

Table 13

Rank sum between both groups

	Group	N	Mean Rank	Sum of Ranks
Q5 Realism and Believability	A	31	32.82	1017.50
	B	25	23.14	578.50
Q6 Realism and Believability	A	31	31.60	979.50
	B	25	24.66	616.50

Note. The sum of ranks of both groups measuring realism and believability in the scenes from Pirates of the Caribbean: Dead Man's Chest.

Table 14

Mann-Whitney U-Test

	Q5 Realism and Believability	Q6 Realism and Believability
Mann-Whitney U	253.500	291.500
Wilcoxon W	578.500	616.500
Z	-2.304	-1.661
Asymp. Sig. (2-tailed)	.021	.097

Note. Mann-Whitney U-Test for realism and believability in the scenes from Pirates of the Caribbean: Dead Man's Chest.

4.2.3 All Quiet on the Western Front

The question Q7 in the survey corresponded to the scenes from All Quiet on the Western Front. The significance level, 2-tailed, was of .068 for Q7. The significance level was above 0.05.

A Mann-Whitney U-Test showed that the difference was not statistically significant between both groups. Therefore, the null hypothesis cannot be rejected, see Table 15 and Table 16.

Table 15

Rank sum between both groups

	Group	N	Mean Rank	Sum of Ranks
Q7 Realism and Believability	A	31	31.90	989.00
	B	25	24.28	607.00

Note. The sum of ranks of both groups measuring realism and believability in the scenes from All Quiet on the Western Front.

Table 16

Mann-Whitney U-Test

	Q7 Realism and Believability
Mann-Whitney U	282.000
Wilcoxon W	607.000
Z	-1.823
Asymp. Sig. (2-tailed)	.068

Note. Mann-Whitney U-Test for realism and believability in the scenes from All Quiet on the Western Front.

4.3 Type of Production

A Mann-Whitney U-Test was carried out for all seven questions. The statements that measured the type of production were: This scene was filmed on a real physical location; This scene was filmed inside of a studio. The results were divided into their corresponding film scenes in the sections below.

4.3.1 Arrival

Questions Q1 to Q4 in the survey corresponded to the scenes from Arrival. The significance level, 2-tailed, was of .163 for Q1, .023 for Q2, .910 for Q3, and .196 for Q4. The level of significance for Q1, Q3, and Q4 were above the level of 0.05, while Q2 was below the significance of 0.05.

Therefore, the null hypothesis cannot be rejected for Q1, Q3, and Q4, and the alternative hypothesis cannot be rejected for Q2, see Table 17 and Table 18.

Table 17

Rank sum between both groups

	Group	N	Mean Rank	Sum of Ranks
Q1 Type of Production	A	31	25.94	804.00
	B	25	31.68	792.00
Q2 Type of Production	A	31	24.37	755.50
	B	25	33.62	840.50
Q3 Type of Production	A	31	28.71	890.00
	B	25	28.24	706.00
Q4 Type of Production	A	31	30.84	956.00
	B	25	25.60	640.00

Note. The sum of ranks of both groups measuring type of production in the scenes from Arrival.

Table 18

Mann-Whitney U-Test

	Q1 Type of Production	Q2 Type of Production	Q3 Type of Production	Q4 Type of Production
Mann-Whitney U	308.000	259.500	381.000	315.000
Wilcoxon W	804.000	755.500	706.000	640.000
Z	-1.396	-2.281	-.113	-1.292
Asymp. Sig. (2-tailed)	.163	.023	.910	.196

Note. Mann-Whitney U-Test for type of production in the scenes from Arrival.

4.3.2 Pirates of the Caribbean: Dead Man's Chest

Questions Q5 and Q6 in the survey corresponded to the scenes from Pirates of the Caribbean: Dead Man's Chest. The significance level, 2-tailed, was of .051 for Q5, and of .593 for Q6.

A Mann-Whitney U-Test showed that the difference was not statistically significant between both groups. Therefore, the null hypothesis cannot be rejected, see Table 19 and Table 20.

Table 19

Rank sum between both groups

	Group	N	Mean Rank	Sum of Ranks
Q5 Type of Production	A	31	24.94	773.00
	B	25	32.92	823.00
Q6 Type of Production	A	31	27.53	853.50
	B	25	29.70	742.50

Note. The sum of ranks of both groups measuring type of production in the scenes from Pirates of the Caribbean: Dead Man's Chest.

Table 20

Mann-Whitney U-Test

	Q5 Type of Production	Q6 Type of Production
Mann-Whitney U	277.000	357.500
Wilcoxon W	773.000	853.500
Z	-1.953	-.534
Asymp. Sig. (2-tailed)	.051	.593

Note. Mann-Whitney U-Test for type of production in the scenes from Pirates of the Caribbean: Dead Man's Chest.

4.3.3 All Quiet on the Western Front

The question Q7 in the survey corresponded to the scenes from All Quiet on the Western Front. The significance level, 2-tailed, was of .641 for Q7. The significance level was above 0.05.

A Mann-Whitney U-Test showed that the difference was not statistically significant between both groups. Therefore, the null hypothesis cannot be rejected, see Table 21 and Table 22.

Table 21

Rank sum between both groups

	Group	N	Mean Rank	Sum of Ranks
Q7 Type of Production	A	31	27.61	856.00
	B	25	29.60	740.00

Note. The sum of ranks of both groups measuring type of production in the scenes from All Quiet on the Western Front.

Table 22

Mann-Whitney U-Test

	Q7 Type of Production
Mann-Whitney U	360.000
Wilcoxon W	856.000
Z	-.467
Asymp. Sig. (2-tailed)	.641

Note. Mann-Whitney U-Test for type of production in the scenes from All Quiet on the Western Front.

5. Discussions

In this chapter is presented the discussion of the results. Followed by the limitations of the research. Finalizing with the ethical considerations of the research.

5.1 Discussions

This study identified three main concepts during the consultation of the literature and the methodology phase: Authenticity, realism and believability, and type of production. Authenticity was divided into two main parts, the authenticity of the material that is being offered, and the emotional perception of authenticity, as Radbourne et al. (2009) described. The statements included in the survey which measured both parts of authenticity were explained in Section 3.3.3. As well as the statements which measured the perception of the audience regarding the type of production. The concepts are discussed separately in the following sections.

5.1.1 Authenticity

The analysis and tests conducted for the data suggest that for Arrival, scene one, scene two, and scene three, reproduced using Virtual Production did not reject the Null Hypothesis of the Mann-Whitney U-Test. However, scene four did not reject the Alternative Hypothesis, see Table 5 and Table 6. These results show that for three out of four, there was not a significant difference between both groups when measuring the authenticity of the scenes. This means that the experimental reproductions for Arrival did meet a similar visual quality than its original scenes. Additionally, the results confirm the statements of Kadner (2019) "[…] A real-time engine has the potential to eliminate many of the bottlenecks of budgeting, schedule, and development time that can prohibit smaller-scale productions from producing imagery on par with blockbusters" (p. 8). Therefore, the experimental reproductions from Arrival confirmed the arguments cited in the literature review. Consequently, the authenticity measured in scene one, scene two, and scene three, can be assumed to confirm **H1**, **H2**, and **H3**, and scene four can be assumed to reject **H1**, **H2**, and **H3**.

The analysis and tests conducted for the data suggest that for Pirates of the Caribbean: Dead Man's Chest, scene one reproduced using Virtual Production did not reject the Alternative Hypothesis of the Mann-Whitney U-Test However, scene two did not reject the Null Hypothesis, see Table 7 and Table 8. A possible assumption on why the two scenes scored differently is because scene one was a more complex scene to film, with more actors, a wider shot where the full costumes and props were visible, and more elements in the scene were seen. On the contrary, scene two was simpler to film, with only one actor, a closer shot, only the top part of the costume was seen, and only the out of focus moving

background was shown. This means that achieving a comparable result for scene one was not achievable with the resources at hand, while scene two, even though the actor was the same, did achieve similar results comparable to the original film regarding authenticity. Consequently, the authenticity measured in scene one can be assumed to reject **H1**, **H2**, and **H3**, and scene two can be assumed to confirm **H1**, **H2**, and **H3**.

The analysis and tests conducted for the data suggest that for All Quiet on the Western Front, the reproduced scene using Virtual Production did not reject the Alternative Hypothesis of the Mann-Whitney U-Test, see Table 9 and Table 10. A possible assumption on why the scene did have a significant difference between both groups could be, again, because the scene was rather challenging to film. The scene was a combination of a wide shot followed by a medium shot, a physical set had to be built with limited budget, and the virtual environment had intricate VFX that were difficult to recreate. All of these factors combined made that the final output of the experimental reproduction did not yield final images comparable to their original scene regarding authenticity. Therefore, the authenticity measured for the reproduced scene can be assumed to reject **H1**, **H2**, and **H3**.

5.1.2 Realism and Believability

The findings of the results regarding realism and believability suggest that for Arrival, all four scenes did not reject the Null Hypothesis of the Mann-Whitney U-Test, see Table 11 and Table 12. The assumption can be made that the experimental reproductions achieved comparable results to their original. A possible assumption on why all four scenes did not have a significant difference between both group could be that they were ideal to film with Virtual Production for various reasons. The virtual environments were simple enough to recreate, and the development of the VFX did not face major obstacles. Although wide shots were included in the scenes, they maintained a sufficient simplicity with no physical set needed. The scenes itself where the heptapods are placed behind the glass panels had the ideal shape of the LED volume, which made the positioning of actors, camera, and aliens to be easily calculated. Therefore, the realism and believability measured on these scenes can be assumed to confirm **H1**, **H2**, and **H3**.

The findings of the results regarding realism and believability suggest that for Pirates of the Caribbean: Dead Man's Chest, scene one reproduced using Virtual Production did not reject the Alternative Hypothesis of the Mann-Whitney U-Test. However, scene two did not reject the Null Hypothesis, see Table 13 and Table 14. The same assumption can be made as with the authenticity measurement. The complexity of scene one did not make it possible to achieve comparable results with the resources at hand. Therefore, most respondents found that scene one had a significant difference than its original, yet, found that scene two did not

have a significant difference. Consequently, the realism and believability measured in scene one can be assumed to reject **H1**, **H2**, and **H3**, and scene two can be assumed to confirm **H1**, **H2**, and **H3**.

The findings of the results regarding realism and believability suggest that for All Quiet on the Western Front, the scene reproduced using Virtual Production did not reject the Null Hypothesis of the Mann-Whitney U-Test, see Table 15 and Table 16. A possible assumption can be made that most respondents found the visuals up to technical standards even though they did not find them on par regarding authenticity. Consequently, the realism and believability measured in the reproduced scene can be assumed to confirm **H1**, **H2**, and **H3**.

5.1.3 Type of Production

The findings of the data analysed about the type of production suggest that for Arrival, scene one, scene thee, and scene four, reproduced using Virtual Production, did not reject the Null Hypothesis of the Mann-Whitney U-Test. However, scene two did not reject the Alternative Hypothesis, see Table 17 and Table 18. These results suggest that most respondents found that three out of four scenes did not have a significant difference on how they believed the scenes were filmed. It can be assumed that although the experimental reproductions and the original scenes were filmed in a different type of production, the majority of respondents still perceived three out of four scenes to have been filmed similarly in both groups. Therefore, the type of production measured in scene one, scene three, and scene four can be assumed to confirm **H1**, **H2**, and **H3**, and scene two can be assumed to reject, **H1**, **H2**, and **H3**.

The findings of the data analysed about the type of production suggest that for Pirates of the Caribbean: Dead Man's Chest, scene one and scene two, reproduced using Virtual Production, did not reject the Null Hypothesis of the Mann-Whitney U-Test, see Table 19 and Table 20. These results suggest that most respondents perceived the making of the scenes to be similar, although in reality they were made differently. Therefore, the type of production measured for scene one and scene two can be assumed to confirm **H1**, **H2**, and **H3**.

The findings of the data analysed about the type of production suggest that for All Quiet on the Western Front, the scene reproduced using Virtual Production, did not reject the Null Hypothesis of the Mann-Whitney U-Test, see Table 21 and Table 22. Once more, it could be assumed that most respondents perceived that the making of the scenes was done similarly, although they were produced with different techniques. Therefore, the type of production measured for this scene can be assumed to confirm **H1**, **H2**, and **H3**.

5.2 Limitations

The study embraced a variety of limitations, some of which had been foreseen, and some which arose during the span of the research. These limitations shaped and guided the scope and design of the research. The first limitation was the lack of existing literature within the Virtual Production industry. This meant that the study had to depend on secondary sources in some circumstances.

The second limitation was the sample size and class of available actors that participated in the study. As the purpose was to closely reproduce existing film scenes, ideally the original actors of the chosen films, or professional actors with a close resemblance to the original actors would have benefited the study to yield a better final image. However, access to the original actors or professional actors was outside of the scope of the study. Consequently, the study relied on the internal workers of the commissioner company to adopt the role of actors. Given the lack of experience of the actors that participated led to another limitation. Instructions on how to perform were challenging to give, which resulted in a need for additional rehearsal, as well as a series of unsuccessful takes due to acting mistakes. Therefore, some compromises had to be made in a few cases where the acting was not up to desired standards.

The third limitation was the time, budget, and size of the crew and collaborators that contributed to the research. The author had to adopt the role of director, producer, camera operator, lighting technician, set designer, and subsequently, of video editor and colourist. Ideally, a team of 3D artists and visual effects experts would have benefited this study by developing computer-generated graphics, models, animations, and visual effects that matched the needs of the selected original scenes. Instead, a single 3D artist fourth year student from the Creative Media and Game Technologies at BUas was in charge of developing all of the aforementioned computer-generated assets. The time constraints of the study also impacted the final product, given that some compromises had to be made during the development and iterations of the virtual environments. Furthermore, the budget available did not allow the acquisition of many film props or premade 3D assets that would have facilitated the creation of the virtual environments.

The fourth limitation was the steep learning curve and nature of Virtual Production when filming image output from real-time engines to a live LED volume in combination with camera tracking. This included learning how to set up and calibrate the camera tracking system for each testing and filming session, learning how to set up the LED volume and understand how to work around it, and a decent level of practical and theoretical knowledge in film and media as well as in game development is necessary to understand what creative decisions

can and cannot be done. The nature of Virtual Production and its physical limitations was also a factor when considering the selection of scenes for the experimental reproductions. As mentioned in Section 3.3.1, certain requirements for the selected scenes had to be met, such as having a subject in the foreground of the scene within a certain distance to the background environment to avoid having the camera focus on the LED volume. This was to avoid unwanted artifacts, flickering, or moiré patterns (Zwerman & Okun, 2024). Additionally, the framing of the shots had to be medium full shots, medium shots, or close up shots to not include any part of the floor, ceiling, or walls. This decision was made to simplify the experimental reproductions based on the scope of this study as well as to maintain the camera framing to stay inside of the physical dimensions of the LED volume to prevent the breaking of illusion. Moreover, the level of VFX or any form of CGI in the scenes had to be manageable to reproduce according to the capabilities of the 3D artist within the time allocated for the research.

The fifth limitation was the accessibility to equipment available for the development of the experimental reproductions. The film equipment was provided by the educational institution and the commissioner company. The author only had access to one camera and four camera lenses options. The lenses available were 24mm, 35mm, 50mm, and 85mm Rokinon Cine DS lenses. Other than the LED volumes, the Vicon Motion Capture System, and the Blackmagic Ursa Mini Pro 12K camera mentioned in Section 2.3.1 and Section 3.3.1, additional filming equipment was necessary to develop the productions. One ARRI Orbiter, one Lupo MovielightPRO 300, two Bresser LG-600 LED lights, and eight Astera Helios tube lights for lighting equipment were available. Ideally, the study would have benefited from having access to multiple ARRI Orbiters, or Lupo cinema lights on top of the other lights mentioned. This would have enabled more possibilities regarding the lighting of the set and actors potentially yielding a better final image.

The sixth limitation was the number of scenes selected for each movie. An equal number of scenes per movie would have been ideal for more accurate results in the data collection and analysis. For the chosen film Arrival, a total of four different scenes were reproduced, while for the other two selected films, only two scenes were reproduced. Therefore, responses could have been bias towards or against the larger number of scenes shown in the questionnaire.

The final limitation was the sampling method and the number of participants required to ensure the reliability and validity of the results. No sampling meant that the results could be acquired from the entire population. Accordingly, responses from the global population would be required, which was outside of the reach for the study. Sampling could not be

representative of the entire population, which may have affected the reliability and validity of the results. In addition, the number of respondents had to be of a minimum of 60 as an experiment AB testing research. However, since there were several variables for the effect of which could not be controlled, the study would normally require more participants. Even though 98 responses were collected from the survey, 40 responses had to be discarded due to an anomaly with the data collection. These responses only answered part one of the survey and did not complete the entire questionnaire although the responses were recorded as complete. On top of that, two respondents opted to cancel, which led to a total of valid responses of 56. As a consequence of the discarded responses, an unequal number of entries was gathered. Group A had a total of 31 responses, while group B had a total of 25. This discrepancy could have affected the validity and reliability of the results.

5.3 Ethical Considerations

This study was conducted in The Netherlands as part of the graduation project, Capstone, of the Bachelor of Creative Business at Breda University of applied sciences. As part of a western European university, the cultural context and access to information might differ from other regions around the world. Furthermore, the data was intended to be collected globally and an international distribution of the survey was done. Nevertheless, most responses were gathered within Europe. This context should be taken into consideration as audience perceptions could be seen differently in other cultures outside of the Western European culture.

6. Conclusion

In the final chapter, the conclusion of this study is presented. Followed by the recommendations for the industry and recommendations for future research. This study aimed to explore the benefits and potential of Virtual Production tools. The goal was to discover whether Virtual Production filmmaking, utilising LED volumes under resource constraints, can yield final images comparable to those in feature-length films.

6.1 Research Conclusion

There are noteworthy differences between the three measured concepts: Authenticity, realism and believability, and type of production.

For authenticity, there is no significant difference between what the independent samples scored for four out of the seven experimental reproductions. Meaning that four out of seven scenes yielded final images comparable to those of their respective feature-length film. For realism and believability, there was no significant difference between what the independent samples scored for six out of the seven experimental reproductions. Meaning that six out of seven scenes yielded final images comparable to those of their respective feature-length film. For type of production, there was no significant difference between what the independent samples scored for six out of seven experimental reproductions. Meaning that six out of seven scenes yielded final images comparable to those of their respective feature-length film.

Looking at the overall results, the experimental reproductions done for Arrival were most successful. All four scenes had comparable results in realism and believability, while only one scene out of four did not for authenticity or type of production. Meaning 10 out of 12, or 83.33% was achieved of the proposed goal. Looking at the experimental reproductions done for Pirates of the Caribbean: Dead Man's Chest, both scenes had comparable results in type of production, while one out of the two did not for authenticity or realism and believability. Meaning 4 out of 6, or 66.67% was achieved of the proposed goal. Looking at the experimental reproductions done for All Quiet on the Western Front, realism and believability and type of production had comparable results, while it did not in authenticity. Meaning two out of three, or 66.67% was achieved of the proposed goal.

Based on the positive results, a strong inclination to confirm the hypotheses of the study can be assumed. Nevertheless, future research should be carried out to further explore the research question, refer to Section 6.3.

6.2 Recommendations for Industry

In the light of the findings of this study, the following recommendations are offered for practitioners in the Virtual Production industry.

After concluding that most of the experimental reproductions confirmed the hypotheses, it is safe to say that Virtual Production is beneficial in some cases. However, the need for skilled 3D artists is highly important to ensure that the content displayed on the LED volumes meets the desired quality and fidelity. This will convey a level of realism and believability to the audience where they might not realise what they are seeing was filmed on an LED volume, which, in hindsight is the main goal of Virtual Production.

Furthermore, additional time allocation on the pre-production phase is needed compared to traditional filmmaking. This means that time spent on the post-production phase shifts to the pre-production phase. The advantage is that the uncertainty discussed in this research ends up being addressed. The production team and actors see the scenes unfold in real time, which enables all individuals on set to be on the same page. Moreover, the virtual environments can be easily modified and rearranged in a more time-effective and cost-effective way.

Virtual Production is not suitable for every situation. Filming on an LED volume has limitations, which were thoroughly discussed in Section 3.3.1 based on the findings of the literature review. Filming wide shots where the floor or walls are visible in camera are achievable, however, more challenging to carry off successfully than medium full shots, medium shots, or close up shots in which only the main subject is in frame. Furthermore, wide shots require more time and expenses to build the physical set that will have to seamlessly blend with the content displayed on the LED volume. Therefore, this study recommends a blend between traditional filmmaking and Virtual Production where wide and complex scenes should be filmed on location or in a physically built set, and narrower shots should be done with Virtual Production. Virtual Production also excels when the setting of the story requires a fictitious background that is challenging to find or achieve in real life.

6.3 Recommendations for Further Research

This research studied the potential of Virtual Production tools to produce final image comparable to those of feature-length films within constricted resources. Particularly, this study only investigated the visual parameters from images outputted by Virtual Production, the reason being that the scope and timeframe did not allow for it. Therefore, to further explore the possibilities of Virtual Production, additional research should be conducted

including the sound and dialogue variables to evaluate the possibility of having a further effect on final image produced through Virtual Production.

Alternatively, this study could have benefited from a qualitative approach to study the validity and reliability of the collected data. This could be achieved by conducting in-depth interviews with participants shown the experimental reproductions and the original scenes to discuss their perception of image quality on a deeper level. The use of in-depth interviews could allow for concepts, that otherwise would have not been chosen, to arise naturally within the conversation from the perspective of the participants. For this reason, a more thorough analysis could have been made in the study. Furthermore, the qualitative approach could have been further expanded with industry expert interviews where valuable insights outside of the knowledge of the author could have been discussed.

Additionally, the sampling for this research could have been narrowed to a specific target group rather than the global population. As mentioned in the limitations, the sampling for this study could not be representative of the entire population. Therefore, a specific target group could have improved the validity and reliability of the results.

Moreover, a total of three movies were selected to be reproduced utilising Virtual Production, including a total of eight scenes. To explore the full potential and capabilities of Virtual Production in small-scale, further research should focus on a larger number of scenes from a variety of different films as well as utilising a different set of film equipment, cameras, lenses, lights, and others.

Finally, the literature identified a variety of practises and types of Virtual Production that were not described extensively, mainly because of the scope and relevancy for this study. However, further research should consider exploring these different Virtual Production practises to further understand the true span of Virtual Production.

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Appendix A

Original Movie Scenes

This Appendix consists of all original film scenes selected in this study in their full length in video format.

Arrival scene one:

A1: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EXEbvSVBvcBGiCwLWATV9hABkdLp7CgfrbhneavS9gVCTg?e=8TlyoE

Arrival scene two:

A2: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EdVk-XxBAMFCnkHxi9XFY-YBt1CEsdstQAD8flSNfaAhZQ?e=aTXPZU

Arrival scene three:

A3: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EdgBaq7YnG1NtKr6bPCabIABXGl0ID0_LdO2lvjzX2uNWQ?e=d5rMY2

Arrival scene four:

A4: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EaqlrBdhVzFGvGFmnXT65V4BQ2vegdbO5CA1AKPJBrs6SQ?e=65YQ1L

Pirates of the Caribbean: Dead Man's Chest scene one:

A5: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EbIx3DZLe-NKjZVpbILhGxwBx3sAaLcYkFQ9dVTi1fl9Hg?e=xkSYyK

Pirates of the Caribbean: Dead Man's Chest scene two:

A6: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/Ef2uEWhjYkJKg7enky1t6fcBbtxE0sarG2KN8S2hOfaoRQ?e=0SDexk

All Quiet on the Western Front scene one:

A7: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EVMsGgT3ZORJkWTJETZWbOgBa_MjAvv8aATu3761qboWzw?e=KXWcNl

All Quiet on the Western Front scene two:

A8: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EUR-xJZp5TNMr-E4yemz5V8B44jT1j20cBnxJGiadWUedg?e=lhqchb

Appendix B

Experimental Reproductions

This Appendix consists of all experimental reproductions from the scenes selected in this study in their full length in video format.

Arrival scene one:

B1: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EQVwEt5jHFJFtCfW7ba2jt8BpNYn6SdL1AKLp2MyDMcaaQ?e=r05Bb1

Arrival scene two:

B2: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EWyr7llfl3xBn20RQjoGBxUBqfUMBFvPOg12sf8hxmQnZQ?e=HLltqP

Arrival scene three:

B3: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EXeCeRHQLvdCnr8ceWy7XCUBHOZodaTXRFBCVgQR9Xf7AQ?e=PAM2nP

Arrival scene four:

B4: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EX-YswFTct1CsfUJviHhOdYBK4kLIvI3ieDlHTWt_clydQ?e=RTxsoY

Pirates of the Caribbean: Dead Man's Chest scene one:

B5: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EXExnSIj0D9OkQJSRga1FwIBC4ifpnODzL3jb7qUJSY1cg?e=vAveRB

Pirates of the Caribbean: Dead Man's Chest scene two:

B6: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EdpHeyFAch5Amp_9NlmXrkABBgsgvh9ycozUltyD3cWrEA?e=CEUFUn

All Quiet on the Western Front scene one:

B7: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/Eb4mVTMMxfRIgnQ9qygHog0Be051HfAaAKwTlNp4HBJxig?e=cRKkxL

All Quiet on the Western Front scene two:

B8: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EUx1-3OAG61Brzbzb80DSuEBUcvhNnJdHxa8idoKFrBTlA?e=Xmm6mb

Appendix C

Survey

Start of Block: Introduction

Q1.1 Hi there!
The purpose of this survey is to collect data for the graduation project of a Creative Business research report at Breda University of Applied Sciences in the topic of **filmmaking**.

In this Survey you will be presented with questions about movies and your preferences when it comes to visual quality in a movie. Please try to answer the questions with honesty based on your own opinion, there are no right or wrong answers.
The survey will take approximately 5 minutes and the responses will be anonymous.
Thank you for your participation!

- ○ I have read the text above. (1)

Page Break

Q1.2 **Disclaimer!**
This survey contains scenes picked from a movie that is R-rated for strong bloody war violence and grisly images. However, the scenes showed here do not include any of the explicit material from that movie. If you feel uncomfortable anyway press on *Cancel* and you will end the survey.

- ○ Proceed with survey (1)
- ○ Cancel (2)

Skip To: End of Survey If Disclaimer! This survey contains scenes picked from a movie that is R-rated for strong bloody war... = Cancel

Skip To: Q1.3 If Disclaimer! This survey contains scenes picked from a movie that is R-rated for strong bloody war... = Proceed with survey

Q1.3 When you look at the visual quality of a film, which of the following statements are most important to you?

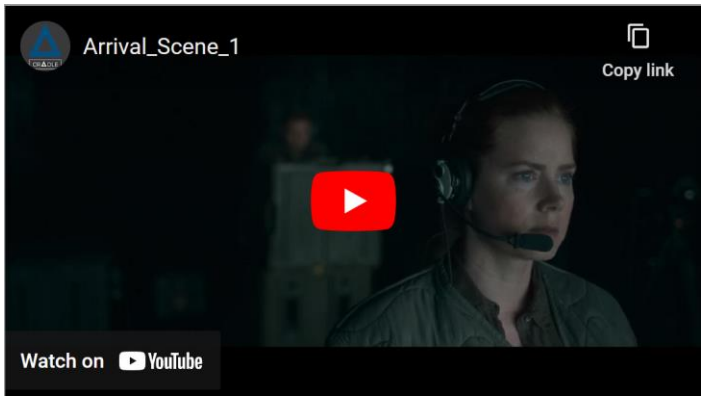
	Not at all important (21)	Slightly important (22)	Moderately important (23)	Very important (24)	Extremely important (25)
The visuals are up to technical standards. (1)	○	○	○	○	○
The visuals seem to be made by the filmmakers that appear on the credits of the production. (15)	○	○	○	○	○
The visuals are of such quality that I believe what is happening is real. (2)	○	○	○	○	○
The quality of the special effects, like real explosions filmed on set. (3)	○	○	○	○	○
The quality of the visual effects, like computer-generated imagery. (4)	○	○	○	○	○
When a film is captured on a real physical location rather than in a studio. (16)	○	○	○	○	○

End of Block: Introduction

Start of Block: Group A

Q2.1 Please watch this video (no audio required) and agree or disagree with the statements below.

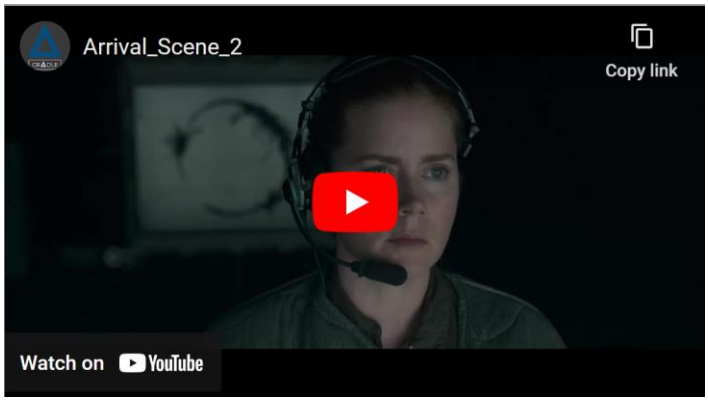
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (2)	○	○	○	○	○
The visuals are up to technical standards. (3)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (6)	○	○	○	○	○
This scene was filmed on a real physical location. (1)	○	○	○	○	○
This scene was filmed inside of a studio. (4)	○	○	○	○	○

Q2.2 Please watch this video (no audio required) and agree or disagree with the statements below.

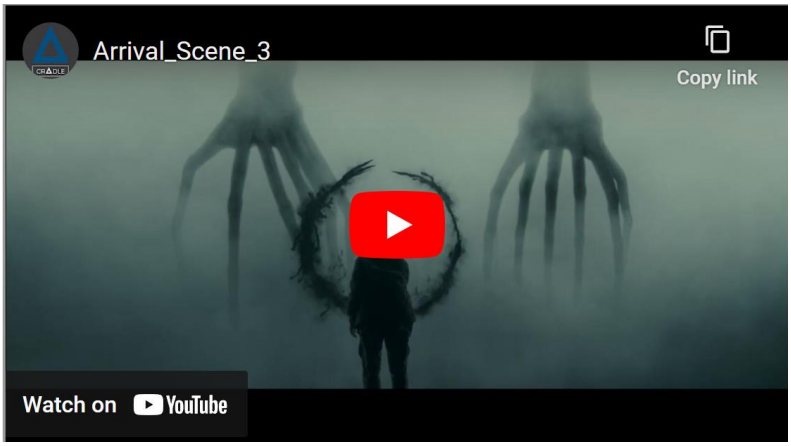
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (2)	○	○	○	○	○
The visuals are up to technical standards. (3)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (6)	○	○	○	○	○
This scene was filmed on a real physical location. (1)	○	○	○	○	○
This scene was filmed inside of a studio. (4)	○	○	○	○	○

Q2.3 Please watch this video (no audio required) and agree or disagree with the statements below.

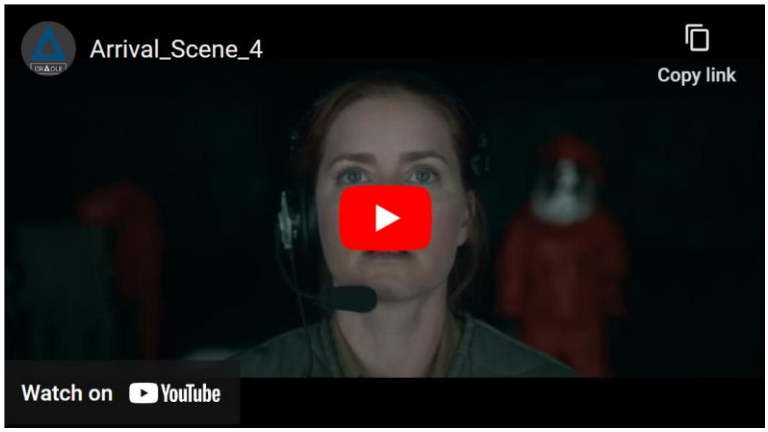
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

Q2.4 Please watch this video (no audio required) and agree or disagree with the statements below.

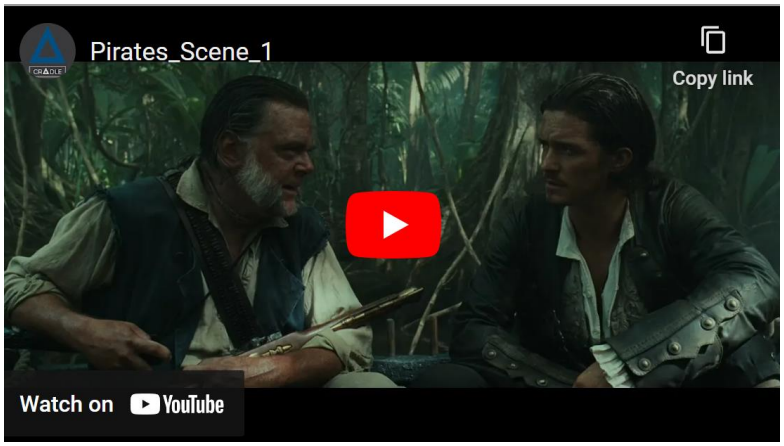
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

Q2.5 Please watch this video (no audio required) and agree or disagree with the statements below.

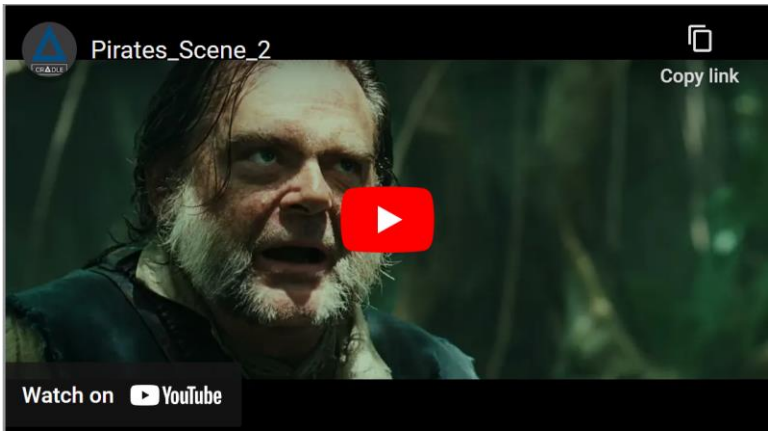
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

Q2.6 Please watch this video (no audio required) and agree or disagree with the statements below.

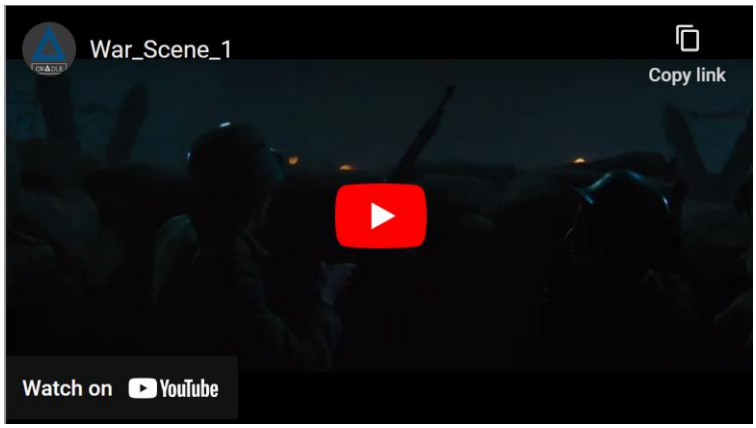
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

Q2.7 Please watch this video (no audio required) and agree or disagree with the statements below.

***Note**: Select the highest video quality if you can.*



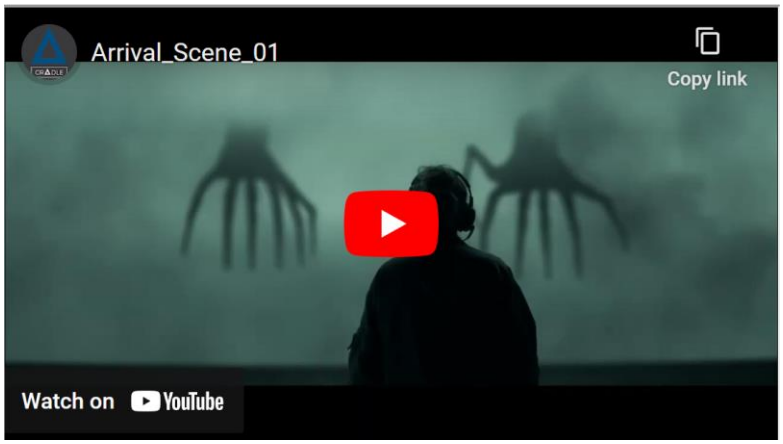
	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

End of Block: Group A

Start of Block: Group B

Q3.1 Please watch this video (no audio required) and agree or disagree with the statements below.

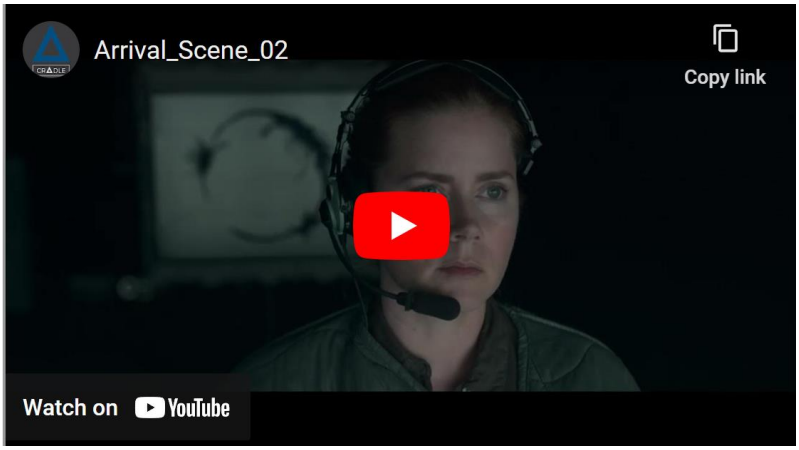
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

Q3.2 Please watch this video (no audio required) and agree or disagree with the statements below.

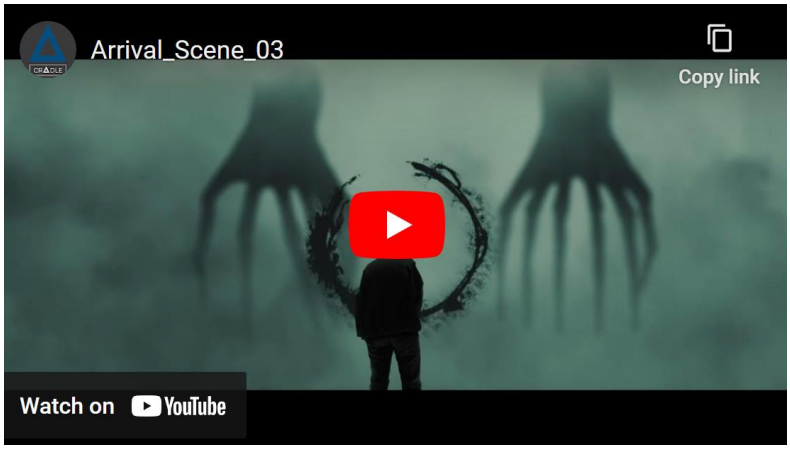
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

Q3.3 Please watch this video (no audio required) and agree or disagree with the statements below.

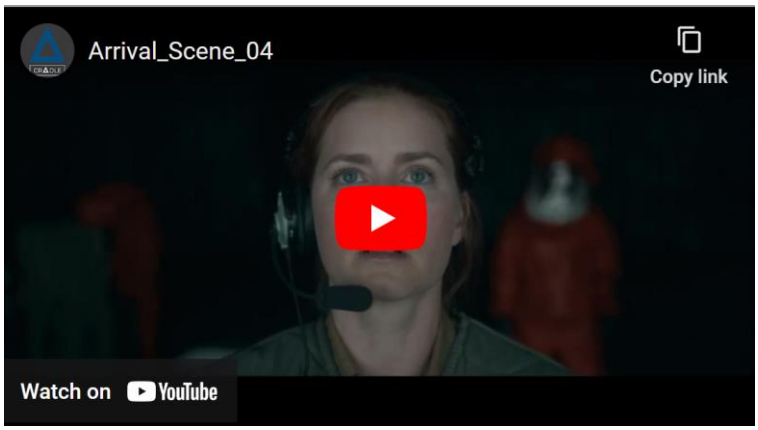
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (6)	○	○	○	○	○
This scene was filmed inside of a studio. (4)	○	○	○	○	○

Q3.4 Please watch this video (no audio required) and agree or disagree with the statements below.

***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (7)	○	○	○	○	○

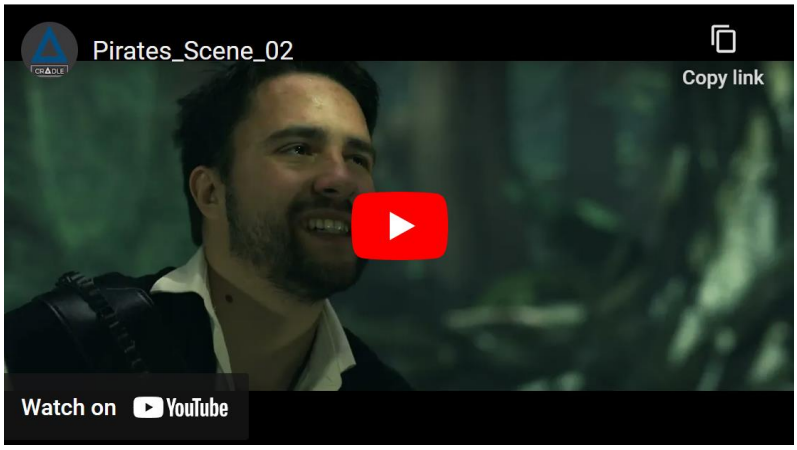
Q3.5 Please watch this video (no audio required) and agree or disagree with the statements below.

***Note**: Select the highest video quality if you can.*

	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

Q3.6 Please watch this video (no audio required) and agree or disagree with the statements below.

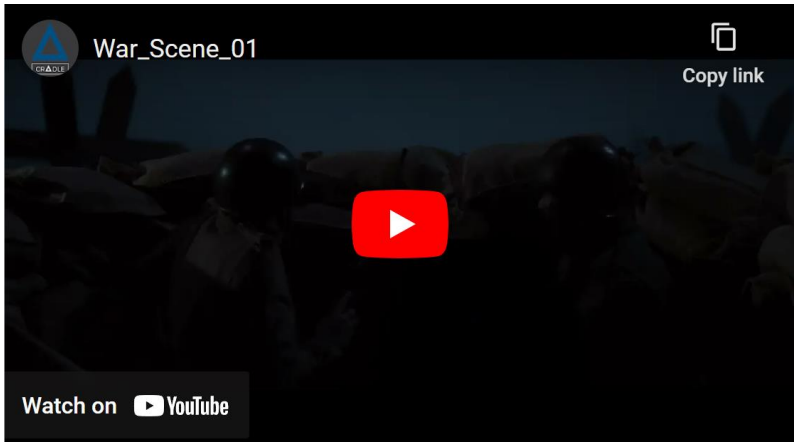
***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

Q3.7 Please watch this video (no audio required) and agree or disagree with the statements below.

***Note**: Select the highest video quality if you can.*



	Strongly disagree (6)	Somewhat disagree (7)	Neither agree nor disagree (8)	Somewhat agree (9)	Strongly agree (10)
The visuals are of such quality that I believe what is happening is real. (1)	○	○	○	○	○
The visuals are up to technical standards. (2)	○	○	○	○	○
The visuals are made by the filmmakers that appear on the credits of the production. (3)	○	○	○	○	○
This scene was filmed on a real physical location. (4)	○	○	○	○	○
This scene was filmed inside of a studio. (6)	○	○	○	○	○

End of Block: Group B

Appendix D

Survey Videos Group A

This Appendix consists of all original film scenes included in the survey for group A in their full length in video format.

Arrival scene one:

D1: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EVhu2b03xAVIs7JsSvlUPXUBAcWfoYLGk0RIkAupbmLINg?e=tTn2as

Arrival scene two:

D2: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EUV6id42AU5Mijj3-B09isUBEuEn5hPwmyAE0KzHQsvp0w?e=qbILZ7

Arrival scene three:

D3: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EQpZrNj_iRIli63cGJ31I4UBcN9HIiJARoDV8r6n9oyC3g?e=62spxs

Arrival scene four:

D4: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EdHKaHgahnBFiOdkctcflEoB1tnkdLuntUtDUHhsBFC16w?e=yNFmwa

Pirates of the Caribbean: Dead Man's Chest scene one:

D5: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EVmyczV_dlJOj3qXKmmMsFABXT6DvJp0sNQYg7ZZ5qP08w?e=o8f2bH

Pirates of the Caribbean: Dead Man's Chest scene two:

D6: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EfTOXihmlrRNl0sGLZFH_8wBrNdJsgoCjBMYMGriBl3ZZQ?e=VqQC67

All Quiet on the Western Front scene:

D7: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EW_28QnEyFJNixAQRq0mucgB_0atbM2XGO5jZn4fzW5a4w?e=0FfKjG

Appendix E

Survey Videos Group B

This Appendix consists of all experimental reproductions for group B included in the survey in their full length in video format.

Arrival scene one:

E1: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/Ed6a6wpuSwJBs4bnKiN1H4wB3XwS0kf-MxaqMVb24u8Cdg?e=LDDCgW

Arrival scene two:

E2: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EeMYdK0bAVtMjr0JdFn1roUBXZ87Ixt01mxkD4kua0dSmQ?e=g1E5vu

Arrival scene three:

E3: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EWX9owBr1clGqXykGpF3ylcBuOaimfDjRy1okw52IZbR6Q?e=tJ3eTt

Arrival scene four:

E4: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EWzjl2y5gudDjnpSh1nC0dQBE2gyAiHgstVhI8v-S4C7wg?e=e2QU51

Pirates of the Caribbean: Dead Man's Chest scene one:

E5: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EbpINW3o9qBNsFEztXVtUvAB1hxNmv62Posfc9c05Q0LAg?e=yMU6it

Pirates of the Caribbean: Dead Man's Chest scene two:

E6: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/EeFg5Zy7jrBDiJIFkzgZ9tEBeba7InDF6Wx2H94Z8CKXCg?e=CsIx6T

All Quiet on the Western Front scene:

E7: https://edubuas-my.sharepoint.com/:v:/g/personal/191585_buas_nl/Efu0IG8bZNJMsiAmHlKQw7cBhMxaGK4BBazxWVuw1AxyOQ?e=rgmyKb