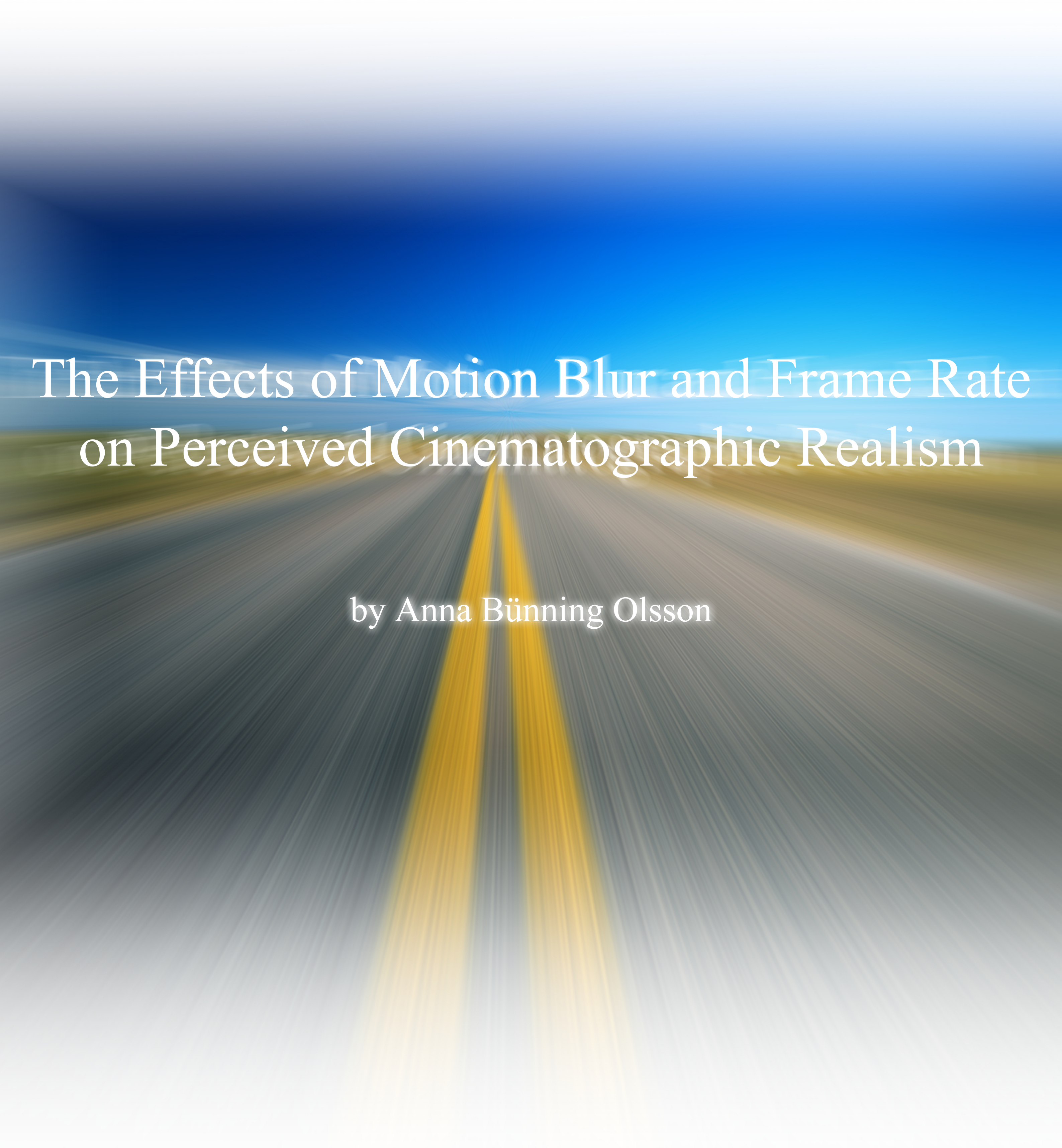

The Effects of Motion Blur and Frame Rate on Perceived Cinematographic Realism

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Abstract:

This report focuses on the effects of motion blur and frame rate on the perceived cinematographic realism of a computer animated scene. Research focuses on what is realism, and how it can be defined within computer graphics. Computer graphics visual effects are researched, to find out why it is we accept them as a part of what we are watching, even when common sense tells us it is impossible.
My problem statement is:
" How is the viewers perceived cinematographic realism of an animated scene affected when watching an animated action sequence at different frame rates and does the lack or inclusion of motion blur affect this perception?"
In my analysis I research further into visual perception, motion blur and frame rate and realism, concluding with test theories.
My test is designed in two groups, those that test different frame rates with motion blur and those who test different frame rates without motion blur, where after the results will be analysed both within test group and across test groups.
Unfortunately my test proved inconclusive due to some errors, though the results that were gathered showed that had the errors not been there, the results might not have been inconclusive.

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1 Introduction

This report will be focusing on realism, looking at the how, why and what makes us believe what we see on the big screen. The focus will be on the more technical aspects of the graphics used to incorporate computer graphics imagery into scenes and make it seem real to the viewer. The aim is to find out how we interpret realism while watching a film and how visual effects may or may not alter our perception of this realism. I also aim to look at how visual effects are incorporated into film and what makes us believe that they are a part of the scene we are watching.

Films are a big part of popular culture, constantly evolving and trying to find new ways to amaze and entertain an ever demanding audience. Film companies are constantly on the lookout for the next big thing the thing that will stand out and make audiences watch their films. This can be an amazing story the audience knows or can relate to, it can be a visual spectacle that the audience can feast their eyes upon, or it can be a mix of the two. This report will be focusing on the technical graphical elements in film, more specifically visual effects.

According the Visual Effects Societies Handbook, "Visual Effects is the term used to describe any imagery created, altered, or enhanced for a film or other moving media that cannot be accomplished during live-action shooting."[Fink and Morie, 2010]. So when one talks about visual effect, the first thing that comes to mind are films such as James Cameron's *Avatar*(2009), Joss Whedon's *Avengers*(2012) and Peter Jackson's *The Lord of the Rings*(2001-2003). These films transport the audience to a distant planet populated by blue aliens, to grand battles between godlike beings and earths super heroes or to middle earth where men, elves, wizards and dwarves fight against orcs and the rest of Saurons minions. Viewers often associate visual effects with imagined worlds and characters, as well as big explosions and humanly impossible action sequences. These are all examples of uses of visual effects that stand out, but are also the visual effects that, if done correctly, pass by unnoticed by the audience.

Visual effects has proven to be a cost effective method of getting grand results on a lower budget. They have the ability to seamlessly transport actors all around the world, and to other worlds if necessary without even leaving the film productions home studio. They have also begun to replace practical effects, as the risk to human life is diminished, and they have the ability to manipulate the results in a completely controlled environment without having to worry about how many takes are used to get it right. Visual effects are also being used in a more subtle manner to correct any "mistakes", by either adding or removing objects or scenery. With visual effects, the goal is to create something that the audience does not notice is not real, essentially if you did not notice it, then it is a job well done. But just how well done does it have to be before the audience notices it? If you add an object to some footage what makes you accept it as part of the environment? Does the live action footage and the digital footage have to interact directly for it to be more real, or does the lighting and attention to detail make it more real? These are just some of many questions that were used to influence the writing of this report.

1.1 Initial Problem Statement

Based on my initial area of interest I decided to begin researching with a broad problem formulation that I will narrow down based on my findings in the pre-analysis. The initial problem statement I decided upon was:

"How do visual effects affect our viewing experience of the perceived realism of a short live action sequence?"

The pre analysis will take a look at the initial problem statement looking into the perception of realism in film, and how visual effects can affect this perception. The pre analysis will end with a final problem statement that will be based on my findings from the section. In the analysis further research will be conducted into the areas that were found to be important in the perception of realism in film, as well as looking further into realism and believability. In the analysis I will also be looking into how humans perceive the world around them based on visual cues, so as to better understand how effects in cinema work. The final part of the analysis will contain an experimental methodology that will look at some of the theories that could be used for the testing of this reports theories. After the analysis is a experimental design where the test of my final problem statement will be outlined. Having outlined the test, the next section will present the design and implementation of a short animation clip. The next three sections in this report will pertain to the summary, discussion and conclusion of test and results. The last section in this report looking at future developments on the experiment, as well as other similar areas of research.

2 Pre-Analysis

In this section I aim to specify on aspects of my initial problem statement firstly looking into the perception of realism in film focusing on how visual effects affect this. From this I will deduce a list of important aspects to take into account when trying to make a visual effects scene realistic. I will then look at some of the research done into these aspects and conclude on what aspects I wish to test on.

2.1 Realism

To understand how the audience perceives realism, it is necessary to understand how audiences have reacted to the spectacles presented on the big screen throughout its history. Most important is to see how the role of cinema has changed from when it started and was a novelty to how it has been altered to suit the demands of its different audiences.

What each individual person perceives as being real or believable is a matter of subjectivity. We are all influenced by our surroundings and daily lives, as David Bordwell and Kristin Thompson, point out *"Realism as a standard of value [..] raises several problems. Notions of realism vary across cultures, over time, and even among individuals."*[Bordwell and Thompson, 2010, p. 118]. If this is the case, then is it impossible to create something that everyone perceives as being real? Stephen Prince [1996a], Professor of Cinema Studies at the University of Pennsylvania, supports the notion that the audiences perception of a film is affected by their personal experiences. In an article for *Film Quarterly* he mentions that *"film spectatorship builds on correspondence between selected features of the cinematic display and a viewer's real-world visual and social experience"*[Prince, 1996a, p. 31]. Prince alludes to the fact that it is not the whole that the audience needs to relate to, but features within the display that the audience can relate to. Charles Musser [2006], Professor of Film and American studies, wrote in his book on cinema in the 1890s explaining how cinema affected the audiences at the time, stating that early cinema was not just the shock of the new, it was the reworking of the familiar not only a reworking of old subjects in a new register but of established methods of seeing and reception[Musser, 2006, p. 176]. This statement highlights the notion that, though we may find the films from that era unimpressive now, at the time they were something new. This is much in the same way that we are left in awe of what modern day effects show us now.

Peter Wollen [1998] in his book on signs, defends the view that realism is perceived on an individual level, by being able to relate to the truth of what is being seen. He writes that "the Realism claim rests on a sleight of hand: the identification of authentic experience with truth. Truth has no meaning unless it has explanatory force, unless it is knowledge, a product of thought."[Wollen, 1998, p. 113]. He goes on to give an example of how we each experience things differently based on our own experiences, "Different people may experience the fact of poverty, but can attribute it to all kinds of different causes: the will of God, bad luck, natural dearth, capitalism. They all have a genuine experience of poverty, but what they know about it is completely different."[Wollen, 1998, p. 113]. He arrives at the conclusion that "Realism is in fact[...]an outgrowth of Romanticism, typically Romantic in its distrust of or lack of interest in scientific knowledge"[Wollen, 1998, p. 113-114], as such realism in media is not necessarily based on real facts, but on our own personal perceptions and what they tell us about the given situation. This is further backed by Gregory Currie [1996], Professor of Philosophy, who wrote in his articles *Film, Reality and Illusion* that film is realistic in that it deploys our natural recognitional capacities.[Currie, 1996, p. 330]. As such it can be established that our perception of realism in film is based on our ability to recognise what we are watching and relate to it in some way, not on whether what we are watching is actually real. Gabriel F. Giralt [2010], Professor at the University of Akron Ohio, in his article for *Journal of Film and Video*, goes so far as to state that "reality is seen not as something to be captured in the purest way possible by the camera lens but rather as something to be constructed.". Again stressing that reality is defined not by what is caught on film, but how it is used to create something new and how we interpret that.

With the inclusion of CGI into films, a whole new discussion arises as to what is real or believable in film now that anything is possible. Ryu [2004] states that "the development of technology determines the representation of reality", holding true to the fact that cinema is constantly evolving, creating new technology that can be used to improve the illusions shown on the screen. Ryu [2007] uses the term *Reality Effect*"to describe the cinematic illusion of reality created by visual effects". This term is used because visual effects make what should be impossible possible, and due to this ability, it "produces a perceptual effect: the audience perceives the artificial representation of impossible events as reality". According to Ryu, visual effects blur the line between "signifiers and their referents" and as a result creates the illusions we see on the screen. These illusions can from time to time dominate over the narrative, thus creating a link to the cinema of attractions.

Stephen Prince [1996a], sees computer graphics as challenging the traditional assumptions that have been made about realism and cinema. He uses the term *Perceptual Realism* to describe an image that "structurally corresponds to viewer's audiovisual experience of three-dimensional space"[Prince, 1996a, p. 32], essentially it is what makes the digital images fit into the live action footage. Stu Maschwitz [2007], former owner of the visual effects company *The Orphanage* writes, in accordance with Prince, that "the only important criterion for the success of an effect is how well it helps tell the story"[Maschwitz, 2007, p. 134]. If an effect goes against the rest of the scene then it will "jar the viewer out of the narrative experience." [Maschwitz, 2007, p. 135], though he also highlights that this does not mean that the effects have to be perfect, if the effect is integrated well into the scene it will pass by the unsuspecting audience. He also highlights that if you want effects to be photorealistic then the scene should be set up so that the shot is something "that *could have been photographed* in some way"[Maschwitz, 2007, p. 138], when effects are added into a scene the filming style should not alter drastically to accommodate for them. Maschwitz gives the example of Steven Spielbergs *War of the Worlds*(2005), where "the massive destruction effects have a messy realism that reflects a physical filmmaking process"[Maschwitz, 2007, p. 140] and due to this the audience believes they are watching real stunts and explosions, when in fact most of it is computer graphics.

Contrary to Prince's *Perceptual Realism*, Assistant Professor of Media and Cinema Studies Julie Turnock [2012] coins the term *Cinematographic Realism* to represent visual effects realism in film. To her visual effects aim to be photorealistic and cannot be seen as part of the viewers perceived realism, since the camera captures certain elements in ways that the human eye does not. She uses the example of lens flare, which can only be seen with a lens and as such cannot be considered a part of perceptual realism due to the requirement of a lens. Turnock considers that "a great deal of stylization is required for effects objects to read as 'realistic' ", this is because computer algorithms provide too perfect solutions that are perceived as unrealistic, as such simple effects need to be added to computer graphics shots in order to make them more realistic. Some commonly used stylizations that Turnock mentions include; virtual hand held cameras, photorealistic lens-flares and roughened surfaces. Turnock also mentions the importance of controlling the viewers gaze by keeping them distracted away from finding any fault in what they are watching. She explains how ILM[1], who created the bulk of the effects for Jon Favreau's *Iron Man*(2008), used the distraction of lights playing over the metal suits to distract the viewers from looking too closely, as well as how low lighting and "post-production 'color timing' provided by the digital intermediate give a textured look to the entire negative, levelling and homogenizing the principle photography and the hard edges of the CGI elements". Turnock's claim that realism in film should be considered as *Cinematographic Realism* has some valid points, though her dismissal of the *Perceived Realism* which is similar to Ryu's *Reality Effect* should be analysed further. The notion that because what we see in film is actually what the camera sees, does not mean that the viewer own perception does not come into play. Though using the word cinematographic to define the realism is fair since what we see in film is highly controlled by cinematography. Turnock also provides some ideas as to what helps computer graphics blend in, such as the addition of lens-flare and handheld camera moves which can be considered as parts of cinematography, as well as using lighting to keep the viewers from looking too closely where they should not.

Having looked at some aspects that Turnock sees as being important for blending visual effects with live action to make it look real, but what else is there and how do they accomplish this technically? Prince [1996a] writes that "digital imaging can anchor pictured objects[...]in apparent photographic reality by employing realistic lighting (shadows, highlights, reflections) and surface tex-

[1] Industrial Lights & Magic is a visual effects company founded by George Lucas in 1975

ture detail[...]At the same time, digital imaging can bend, twist, stretch, and contort physical objects in cartoonlike ways that mock indexicalized referentiality."[Prince, 1996a, p. 29]. As such it can be gathered that lighting, and in connection shadows, as well as texture are important when creating realistic computer graphics imagery. He also speaks of a distortion or exaggeration that goes against real world realism, but is often accepted in film and is sometimes perceived as being more realistic than reality. In an article for the University of Southern Californias online magazine *Illumin* Jason Scott [2002] writes that "A 3D image that looks and moves in mathematical accordance with reality can still look wrong to a viewer on a television screen or in a movie theatre." He uses an example from *Harry Potter and the Philosophers Stone*(2001) where they had to simulate the actors flying on broomsticks. The issue being that if their clothing was animated to the correct speed, about 300 miles per hour, it would rip them right off. So instead they were animated at 60 miles per hour, which gave a perceptively more realistic look. Scott concludes that there are two directions that research can go in, one is to focus on "absolute physics-based simulation and photorealism" where getting as close to the real world is the objective, while another is "giving viewers images that enhance their imagination and assist in the telling of a story". Looking further into what makes visual effects acceptable in film will judge which path is the most prudent to take, though from the research conducted thus far, visual effects do not need to be photorealistic, they should instead be used as a tool to embellish and help tell a story. From this we can gather that Scott sees the importance of using visual effects to help tell a story, and that it is not necessary to create something that follows physical laws, just as long as it produces a visually believable images.

Computer graphics programmer and lecturer at The University of British Columbia, Robert Bridson [2011] supports the use of exaggeration and writes that "in photorealistic visual effects work where subtly exaggerating motions, lighting effects, dimensions, etc. can convey a clearer and perceptually more real experience[]you can see how much exaggeration[]is necessary just to accurately portray what we believe we perceive everyday". This mention of exaggeration refers to Pixar artist, John Lasseter [1987] *Principles of Traditional Animation Applied to Computer Animation*where he writes that "exaggeration in animation does not mean arbitrarily distorting shapes or objects or making an action more violent or unrealistic. The animator must go to the heart of anything or any idea and develop its essence, understanding the reason for it, so that the audience will also understand it"[Lasseter, 1987, p. 41] Essentially, if someone is angry make them furious, if they are brooding make them dark and forbidding, it is taking a mood to the extreme and at times even having the environment reflect character moods. Lasseter indicates that exaggeration should not happen in isolation, there should be a balance between the aspects that are exaggerated, "if just one thing is exaggerated in an otherwise lifelike scene, it will stick out and seem unrealistic." [Lasseter, 1987, p. 41]. He warns against completely exaggerated scenes, and suggests that there should always be some aspect that the viewers can recognise as natural so that it grounds the scene as a whole.

Director of Graphics Research and Development at Pixar Animation Studios Anthony Apodaca and Larry Gritz write in their book[Apodaca and Gritz, 2000] that initial research into making computer graphics more realistic was focused on "solving such problems as accurate light, reflection models, motion blur, depth of field, and the handling of massive visual complexity"[Apodaca and Gritz, 2000, p. 4] due to the demands of the film industry. It was argued that "in order for the audience to understand and believe the movies world, it clearly has to be realistic" but it should be noted that "movie realism and physical realism are two different things"[Apodaca and Gritz, 2000, p. 5]. When we watch a film we have come to subconsciously expect certain things from it. Apodaca and Gritz refer to the "visual language" developed by filmmakers that allows them to clearly tell their stories. This language removes all details that are considered distracting or confusing, even if they are realistic, and accentuates details that may be unrealistic, to keep the viewer "focused on what the director wants them to watch"[Apodaca and Gritz, 2000, p. 5]. As such film, even without visual effects, does not look like real life photography, as it has always manipulated the world to better tell its story. Though he also points out that "when a CG special effect is added to a shot, the perceived realism of the effect is more influenced by how well it blends with the existing live action footage than by the photorealism of the element itself."[Apodaca and Gritz, 2000, p. 5]. Thus, Apodaca and Gritz see computer graphics imagery as being 'based in realism', but that this realism, is moulded to the directors vision and due to this he calls it *photosurrealistic*. *Photosurrealism*, similar to Turnock's *Cinematographic Realism*, is an apt term for what visual effects are trying to achieve. Rather than calling it photorealism, which is what Turnock considers the realism to be, Apodaca and Gritz see realism in film as being subject to each filmmakers own filmic vision.

Though the initial research was focused on recreating realistic lighting, reflections, motion blur, etc Apodaca and Gritz conclude that viewers do not always notice the realism in these aspects. With regards to lighting they write that "viewers generally do not know where the lights are located in a scene"[Apodaca and Gritz, 2000, p. 6] and so it is not a requirement that the light paths behave realistically in order to ensure that an image is believable". With regards to reflection, it is important to have it, but "viewers have so little intuition about the reflection situation that almost any approximation will do"[Apodaca and Gritz, 2000, p. 8]. As such, a degree of realism is important to have, but that it is unnecessary work to try and aim for photorealism with regards to lighting and reflections.

Apodaca and Gritz also note that motion blur, depth-of-field and the handling of massive visual complexity are important aspects for the creation of realistic scenes, though they does not go into what research has been done in each area, due to this they are opportune areas to look into. The handling of massive visual complexity is looking at ways in which computational costs can be made more efficient, I will be referring to it as level-of-detail(LoD). Depth-of-field(DoF) is the focusing ability of the camera, where only one plane in three dimensional space is in perfect focus. With virtual cameras every plane is in perfect focus, so it needs additional information to defocus certain planes or when rack focus is used, to switch from foreground to background being in focus. The final point that Apodaca and Gritz mention is motion blur which, like DoF, is a blurring of the image, and adds a certain credibility to cinematic images since we are used to seeing it in film. Bridson [2011] writes that "realistic motion blur is generally desired to help with the suspension of disbelief". This is supported by Prince [1996a] who adds that motion blur is added "to simulate the look of a photographic image"[Prince, 1996a, p. 30] due to it occurring naturally in film when the shutter speed is too low to freeze moving objects. It does not occur naturally in computer graphics, as Isaac Kerlow [2009], director and animation expert, points out in his book on 3D computer graphics and animation. He writes that "motion blur is a form of temporal aliasing that results from samples that are too far apart to capture motion details"[Kerlow, 2009, p. 282]. We accept this blurring of images as "Motion blur can add a touch of realism to computer animation because it reminds viewers of the blurring effect that occurs when we records fast-moving real objects directly with a camera"[Kerlow, 2009, p. 283]. This is true unless you use a high speed motion camera that is capable of freezing objects in motion by recording a high number of frames per second. With a film such as *The Hobbit: An Unexpected Journey*(2012), the first motion picture to be released in 48 frames per second(fps), the amount of motion blur will naturally decrease due to the increase in shutter speed. Though there was a large amount of hype as to the supposedly increased realism due to the extra frames, many viewers found the increased frame rate distracting and unrealistic[Fenlon, 2012]. As such motion blur, both by itself and in relation to frame rate, is an area to look into as it adds to the sense of realism in fast moving scenes.

Throughout this section I have looked at what makes us perceive visual effects as being part of a scene and, as such, realistic. Based on the research I can conclude that lighting and shadows, texture, level-of-detail, motion blur, frame rate, exaggeration, depth-of-field and camera movements are all important aspects to consider when trying to create something that is to be perceived by the viewers as being real. Also noted in this section are four different views of the type of realism represented by visual effects. These are Ryus *Reality Effect*, Apodacas *Photosurrealism*, Turnock's *Cinematographic Realism* and Prince's *Perceptual Realism*. I have earlier concluded that realism in film is based on each individual person's personal experience and perception, and as such have been calling realism in film, perceived realism, which is similar to Prince's and Ryu's take on realism. Apodaca and Turnock have a similar view on filmic realism, which is that it is not based directly on the viewers perception but on the cameras perception, though they differ when they considering the importance of photorealism. Having analysed each view, I have chosen to refer to realism in film as *Perceptual Cinematographic Realism* as I believe that the viewers own perception is as important as the cinematographic stylisation in determining the realism of what is shown. In the next section I will look into what has been researched in terms of realism and how these different aspects affect film viewers.

2.2 Visual Effects

The previous section focused on what technical aspects helped visual effects to be perceived as being realistic in film, this section will now focus on the research done into these areas. I will conclude by looking at the research and determining whether there are aspects that have not been looked at and how promising further research in that area would be in terms of perceived cinematographic realism. I will go through the aspects as follows: lighting, shadows, texture, level-of-detail, motion blur, frame rate, depth-of-field, exaggeration and camera movements. Some of the papers involve the use of visuals in interactive situations such as games and virtual reality which leaves open the possibility of testing the same aspects but in a non interactive situation.

I will start by looking into the research done on lighting and shadows. Lighting is a popular area of research as it is a large part of what controls mood and as such has a great effect on viewers perception within films. Ann McNamara [2006] focuses on the rendering of light and how the human visual system (HVS) reacts to lighting. Her research suggests that only two inter-reflections are necessary in diffuse enclosed scenes, as more does not make a difference in image quality and will only increase computational costs. In this paper the focus is on diffuse scenes and she suggests further research should be conducted into how direct and indirect lighting works in similar situations. She also touches on the idea that darker images can be rendered to a lower precision than light images, without it affecting the images overall quality. Ferwerda et al. [1996] focus on global illumination at different intensities, their research looking at the HVS and how visual acuity is affected by luminance[2]. The result of their experiment is a model that generates images as seen by the HVS under different lighting intensities. Though they suggest that the results require further work, it provides insight into how our eyes work and provides an initial model that predicts the change in threshold visibility.

Křivánek et al. [2010] research the effects of global illumination approximations on material appearance, using virtual point light(VPL) algorithms[3]. They looked at how image quality is affected by the VPL algorithms, focusing on creating artefact-free images and getting accurate material appearances. They got users to determine between two images whether one had artefacts, and using a third as a reference, asked which objects material was different from the reference images. Their results show that VPL has a large impact on equivalence, and can cut down on render time, though for glossy objects a very high number of VPLs are necessary for artefact free images. Also geometrically complex objects and diffuse materials are more forgiving of the algorithm whilst geometrically simpler objects require a larger VLP count to achieve similar results and metals cannot necessarily be rendered accurately. As such it can be gained from Křivánek et al. that VPL algorithms are good for complex scenes that do not have too many glossy surfaces, otherwise there appear too many artefacts and materials may change. To avoid this other algorithms based on VPL have been developed, namely bidirectional physics based rendering systems[Dammertz et al., 2010] and virtual spherical lighting[Hašan et al., 2009].

Pablo Mauricio Rademacher [2002] created an experiment to test the perceived visual realism of images based on some predefined criteria. He created two sets of images, one set contained only real photographs of some objects, whilst the other set contained only computer generated images of the same objects. In each set he varied some aspects: shadow softness, surface smoothness, number of objects, mix of object shapes and number of light sources. He perceived that a computer graphics image should evoke the same sense of realism as a photograph. He reaches the conclusion that physical accuracy is not equivalent to perceived visual realism, though shadow softness and surface smoothness showed some statistical significance, the other aspects did not. Surface smoothness was based on comparing a smooth surface with one that appeared to be made of wood, suggesting that smooth surfaces are more readily believed to be 'fake' whilst even just adding a texture makes it more believable. The shadow smoothness results suggest that we do not see spotlight shadows, that

[2]Luminance is where our eyes are very sensitive under dim illumination and we can detect small differences in luminance, though our ability to distinguish colour is reduced. The opposite is true in bright light, where we can clearly see colour, but have little sensitivity of luminance.

[3]VPL is where a light path is traced through a scene, at each vertex where the light bounces off a surface a virtual point light is created. The benefits of this method are that it produces images with low noise and has a scalable performance. A side effect of this method is that artefacts appear, and that clamping is necessary which can lead to distortions in material appearance.

are clearly defined, as being as real as the softer shadows where the penumbra is greater. Again Rademacher's experiment is performed on photographs, suggesting the same experiment could be performed with moving images, and due to the response to surface texture, more materials could be experimented with to see how viewers react.

Textures are used to enhance models and provide details that would be too costly to model. Squires [2010] indicates how smooth objects are considered small, whilst adding detail makes an object look larger, also mentioning that a CG model without detail looks small or is likely fake. This is mirrored in nature where everything is incredibly detailed if you look close enough. Issac Kerlow [2009] outlines how texturing techniques can be split into two groups; visual and spatial textures[Kerlow, 2009, p. 276-278]. Visual textures do not affect the geometry of the model they are on, being two dimensional simulations of three-dimensional texture, whilst spatial textures can affect the geometry and the smoothness of the surfaces they are on[4]. In an article Blinn and Newell [1976] outlines an algorithm that increases the 'naturalness' of patterns and textures by giving them the ability to simulate reflections. Paul Heckbert [1986] researches texture mapping looking at the geometric mappings that distort a texture onto a surface and the filtering that is needed to avoid aliasing. He also highlights that though textures are usually easier to compute than complex geometry, when we use high-resolution images the time it takes to render is higher than with a low-resolution image. Wang et al. [2003], introduce a technique called view-dependent displacement mapping(VDM), which focuses on real time rendering and the effects, shadowing, occlusion and silhouettes, that are associated with it. The aim of VDM is to allow for efficient rendering of effects without increasing the complexity of the mesh it is placed on. Dana et al. [1999] research real world surfaces and their appearances, discussing a new texture representation called Bidirectional Texture Function(BTF), related to bidirectional reflectance distribution function, that captures the variations in texture with regards to illumination and viewing direction. Their research provides a point of reference to test and compare Bidirectional Reflectance Distribution Function(BRDF) models, having stressed the need for 3D texture rendering algorithms and seeing their database as a first step in that direction. Based on the research quite a lot has been done to bring textures closer to photographic realism by adding details, while at the same time using textures to create illusions of more polygons so as to keep computational costs down. This research suggests that further work could be done perfecting the current algorithms, to either improve texture reflections, the accuracy of displacement maps or to look into 3D textures.

Textures are one way of keeping scene computational costs down, another way to handle massive visual complexity in a scene is to adjust its level-of-detail(LoD). LoD is most relevant in real time rendering, but it is also a way of cutting down on rendering time in films. Martin Reddys main area of research has been the attempt to optimise level of detail for use in real time computer graphics rendering[Reddy, 1997, 2001]. Reddy explains the common approaches to decreasing the LoD are polygon reduction, texture mapping or illumination models and proposes an algorithm, based on human visual perception, that would assess the visible content of a computer generated scene and alter it accordingly. Reddy [2001] states how "we can perceive less detail in the peripheral field of our vision" and that "our eyes are less sensitive to detail that moves rapidly across the retina, [...] level of background illumination, pupil size, exposure time, the viewers level of light adaptation, optical deficiencies such as myopia and age". All these factors contribute to ways in which graphics can be optimised in order to speed up render time, but does not necessarily increase perceptual cinematographic realism. This suggests that LoD optimisation, though a very relevant area within real time graphics rendering and virtual environments, is not overly relevant in films as these do not require the graphics to be computed during real time.

Further aspects of cinematography that were perceived as being important for perceived cinematographic realism in film are depth-of-field(DoF), exaggeration and camera movements. According to Rickitt [2007] DoF is "The distance in front of the camera over which objects appear to be acceptably

[4] Examples of visual textures are basic colour textures whilst spatial textures tend to be monochrome some examples are bump maps, displacement maps and transparency maps. Bump maps alter the direction of the surface normals so that when lighting hit the objects surface it gives the illusion of 'bumps'. Displacement maps not only alter the surface normals, but also alters the models they are place on. Transparency maps are used to make all or parts of a surface transparent, using the monochromatic texture map to decide which parts should be transparent, opaque or translucent.

in focus[...]Depth of field is affected by the focal length and aperture of the lens on the camera, the amount of light in a scene, the shutter speed of the camera, and the speed of film being used"[Rickitt, 2007, p. 371]. As such there are many aspects to consider when creating DoF. Joe Demers [2004] concludes that there is not one DoF algorithm that suits all needs, as some weigh quality over speed and vice versa. He states that when it is quality over speed, ray-tracing or accumulation-buffer DoF algorithms are the best choices, whilst layered or z-buffer DoF algorithms are best when processing speed is more important than quality. In his article Demers focuses mainly on z-buffer DoF algorithms and concludes that there are some issues with the method. These issues are depth discontinuities, bilinear interpolation and pixel-bleeding[5]. Held et al. [2010] look at how blur helps us determine distances and sizes, finding that blur helped make big things look small and small things look big. Also their research stands against the notion that DoF is a weak depth cue and though distance cannot be measured by DoF alone it can be effectively measured together with other depth cues. Hillaire et al. [2008a] research DoF in a first person shooter games, concluding that it made the game slightly harder, but it could be used for navigation at times when the player is less stressed and not forced to explore the whole image to find enemies. In another paper Hillaire et al. [2008b] use eye-tracking to improve the users' experience of first-person navigation by adjusting it to each individuals focus point. Again the DoF condition is not clearly preferred to the condition without, though with the eye tracking it was significantly preferred when it came to fun and immersion. In both papers they also note the uses of DoF in other contexts such as architectural designs, where it could be used to improve perception of depths and distances in the virtual world. Kosara et al. [2001] present the notion of *Semantic Depth-of-Field*(SDoF), where objects can be blurred based on their relevance rather than their distance. Their technique makes it possible to highlight relevant objects in a scene without distorting the geometry or other visualisation features, and as such makes it a good tool for presenting data or pointing out information in tutorials. DoF is an aspect being studied, not only for films, but also for computer games and other interactive interfaces, its uses being similar in the different medias. This research does not suggest whether DoF increases the realism of what we see, but rather it is a tool for highlighting or pointing out what we should look at in a scene.

Exaggeration is an aspect that is most commonly seen in animations, though by the definition explained in the previous section, exaggeration helps to accentuate important aspects of a character, environment or object. Exaggeration is at times used to avoid Masahiro Mori's Uncanny Valley, where the closer you get to realism the greater the risk of alienating the audience. Hodgkinson [2009] writes that exaggeration can compensate for the unrealism of animation, by drawing from the real world yet consciously taking it further. Soon and Lee [2006] research a low polygon method to exaggerate distinctive features of detailed high polygon 3D faces, where the exaggeration is used to make the models more recognisable. Wages et al. [2004] found that reducing the number of features while exaggerating certain ones had a greater effect than sticking close to biological realism. Exaggeration is very much dependant on the situation where it is used, either for comic relief or to highlight an important feature, or personality trait, of a character. There is not much research in terms of creating a scale for how much exaggeration should be used or, when and if exaggeration is ever considered as realism. Though there may be no direct link to realism, all the sources agree on the importance of exaggeration to add personality, though care should be taken that it does not end in the uncanny valley.

Camera movement is another aspect that was perceived as important for perceptual cinematographic realism. Having established that it is important for virtual cameras to move in accordance with accepted cinematography, Squires [2010] further supports this by highlighting how virtual cameras can do everything and anything, but that caution should be had to not misuse this ability. He writes that if the aim is to be realistic, then non-photoreal camera movements or stylized imagery can break the audience focus. He uses the example of complex action sequences where it is best to keep camera motion to a minimum, so the audience can focus on the action. Kurz et al. [2010] research a method that allows for convincing addition of camera shake to virtual imagery, considering that it increases the realism of a shot by giving it a rougher feel. Kurz et al. focused on not creating a

[5]Of the three presented, the one that stands out the most is Depth of discontinuities due to the fact that only one z value is used to determine what to blur, if the object is in the foreground it fails to blur our, giving it sharp edges. Bilinear interpolation occurs when you magnify the smaller mipmaps or blurred images, resulting in square stair-stepping patterns. Pixel-bleeding is the least objectionable and is where areas in focus can bleed into the nearby areas that are out of focus creating a halo around the objects in focus

repetitive cycle, but including small details that alter the movement cycle to make it more realistic. Jardillier and Languénou [1998], Kennedy and Mercer [2002] and wei He et al. [1996] have looked at ways of implementing a tool that helps with camera positioning in virtual environments. This tool would base its choices on established cinematographic principles. This research has supported the notion that camera movement is important when trying to approach perceived cinematographic realism, by highlighting the need to have imperfections in the shots and to take care with the unlimited possibilities of a virtual camera. The research on camera movement has focused mainly on how to get the computer to replicate these, and how they can be translated into other interactive scenarios. This leaves open the possibility of directly analysing the movement of cameras in film and how they alter the viewers perception of what is happening in a scene.

Another aspect found to be important for perceptual cinematographic realism is motion blur. Motion blur as defined by Richard Rickitt [2007] as "the blurring that occurs if an object moves when the shutter is open during photography"[Rickitt, 2007, p. 373]. As such motion blur is actually a technical failing, though it helps the human eye to perceive the images as being more natural "by preventing the strobing that would occur if objects moved from frame to frame without blur"[Rickitt, 2007, p. 373]. Motion blur has to be added separately to stop motion and computer graphics animations since neither medium contains it naturally and as such research has been conducted to optimise the process of adding motion blur. Navarro et al. [2011b] discuss the state of the art within motion blur, which is often used to increase the perception of motion in photographs, highlighting the different algorithms that can be used and underlining the heavy computational costs of motion blur. They express that research tends to focus on improving sampling schemes for the rendering process and the implementation of more efficient algorithms, suggesting that there is a lack of research done into the relationship between the HVS and the way we perceive objects in motion. Fischer et al. [2006] research the addition of image noise, edge aliasing and motion blur, to help blend virtual objects and video images in augmented reality applications. Fischer et al. identify these three aspects as being what distinguishes the virtual objects from the video images, and create an algorithm that can apply these aspects real time. This research supports motion blur as an important aspect of the perceived cinematographic realism, and suggests that looking into the HVS and applying this to a test with motion blur could yield insight into how we perceive objects in motion, the bulk of the research having focused on optimising motion blur algorithms.

With the introduction of high definition cameras, the amount of motion blur began to decrease in filmed footage, and as such needs to be added when required. This is due to the high frame rates that diminish the strobing effect between frames. McCarthy et al. [2004] compare the effects of quantization, frame quality, versus frame rate for streamed videos. They conclude that participants were more sensitive to reductions in quantization than to changes in frame rate, exemplifying that the viewers did perceive the graphics as not being smooth at 6fps, they accepted it most of the time. This suggests that the notion of fast motion requiring high frame rate, is incorrect. Claypool et al. [2006] found that in a computer game frame rate has a larger impact on player performance than frame resolution. Frame rates as low as three to seven fps was almost unplayable, whilst it was shown that users benefited greatly when playing at 60fps. This is contrary to what is said about video, where higher resolution was more important than higher frame rates, with frame rates at three to seven fps being acceptable. Frame rate is an area of relatively little research in terms of its affect on film viewers, especially since at this point in time only one film has been released at 48fps. The research thus far suggests that higher frame rates break the audiences willing suspension of disbelief, though no research has been done to directly test this affirmation.

It can be concluded that a lot of research has been conducted in terms of creating realistic computer graphics renderings. A lot of the research has focused on testing still images, which leaves the question of whether the results will change when the image is not static. The areas with least research in terms of film were shadows, camera movements and exaggeration, possibly due to the former being taken for granted with lighting, and the latter because they are considered part of the basics in computer animations. Soft shadows with penumbra are perceived as being more real than hard shadows, exaggeration helps increase recognisability of objects and rough camera movements in CG shots increases the PCR. Lighting is one of the areas with the most research having determined that; only 2 light reflections are necessary, darker images have lower perception than light and that glossy surfaces are the most complex to realistically recreate. It is also suggested that more research should be done related to the HVS, which is also the case with motion blur and frame rate. Motion blur, considered important when blending real and CG footage, and frame rate are both associated with fast motion, though the research suggested that fast motion does not require a higher frame rate. The research suggests that increasing frame rate breaks the suspension of disbelief in an image, whilst lower frame rates become more jerky resulting in less perceived realism. The research implies that the more detail a texture has the larger and more real it is perceived to be, whilst less detail makes a texture appear smaller and fake. This is linked with LoD, which was found to be more important for real time rendering, though the theories can also be used if animators want to decrease render time. DoF is useful for guiding the audience's eye in a scene, as well using SDoF to highlight various objects regardless of their distances. There are many algorithms focusing on perfecting DoF for CG, though often they weigh either quality over speed or vice versa. Based on all this research I will choose to look at motion blur and frame rate, as these are areas that are linked, in their use for perception of speed, and are not over analysed but contain some research that suggests their validity.

2.3 Final Problem Statement

This section has researched various areas based on my initial problem statement which is:

"How do visual effects affect our viewing experience of the perceived realism of a short live action sequence?"

I looked into realism in cinema, both with and without visual effects, finding out what aspects make visual effects seem real in film. I also determined that the realism I am researching is better defined as Perceived Cinematographic Realism due to the realism in film being a matter of personal choice as well as the following of certain cinematographic prerequisites. Having determined some aspects that make visual effects seem real I proceeded to look into a brief state of the art within these aspects. I decided to choose motion blur and frame rate as these aspects are linked and have been the focus of some research, without being overly researched. Based on my conclusions my final problem statement will be as follows:

"How is the viewers perceived cinematographic realism of an animated scene affected when watching an animated action sequence at different frame rates and does the lack or inclusion of motion blur affect this perception?"

To test this problem statement I will need to research further into motion blur and frame rate, to find out how they can be adjusted and tested. I will also look into human perception of motion and how frame rate affects humans. I will look into realism again with the aim of specifying it further and figuring out how to test it. I will also look at methods of testing passive viewers, such as eye tracking, questionnaires and observations to determine how to get the most unbiased results.

3 Analysis

This section will focus on going further into depth within the chosen area, and finding the best solution to test the final problem statement. I will expand on the research done into frame rate and motion blur. I will also be looking at visual perception, focusing on the perception of motion, as one of the reoccurring point in the research has been that the research should be more focused on the human visual system. Going on from perception I will look more into realism to better understand what is realism, and I will be finishing off the analysis with the methodology, outlining the methods that I will be using to test my research hypotheses.

3.1 Motion Blur and Frame Rate

Having concluded in the pre-analysis that I will be focusing on motion blur and frame rate, this section will now present further research into each aspect concluding on how I will test each aspect.

A lot of research has been done to improve the algorithms that add motion blur to images that do not contain it[Brostow and Essa, 2001, Fischer et al., 2006]. Navarro et al. [2011a] presents research into the perception of motion blurred images, achieving a method that reduces the computing requirements of the motion blur rendering process. They explore psychophysical experiments and conclude that in certain cases, images can be rendered using aggressive simplifications without degrading the perceived quality. These simplifications can be applied to object material and speed, shutter speed of the virtual camera, and the antialiasing levels applied by the rendering algorithm. Though their method shows different results, when compared side by side with other computationally heavy algorithms, they are perceptually indistinguishable when played under their experiments conditions. Rosado [2007]analyses a method of applying motion blur as a post-processing effect in games, considering motion blur to be important as it helps to smooth out a game's appearance. This is especially significant when the game is rendered at 30fps or less. He also highlights how it is a vital effect in racing games, due to the perceived increase in realism and sense of speed.

Kawagishi et al. [2003] look at a method of emphasising motion in cartoons, termed cartoon blur. Cartoon blur functions like motion blur in that is creates an after-image, but it is often in a non-photorealistic sense. They highlight three categories of cartoon blur; Lines along the motion path, after image replicating the character and deformation that creates jagged contours. It is relevant to considering cartoon blur for this project as my problem statement states I will be creating an animation, which allows me to use less realistic forms of motion blur.

Pang and Tan [2010] point out how Liquid Crystal Displays(LCD) have taken over the market from Cathode Ray Tubes(CRT), though LCDs are not without issues. Motion Blur is one of the principle issues that LCD screens have. CRTs are better than LCDs when it comes to showing fast motion and this is due to the rendering method used called *impulse-type*. LCDs use *hold-type* rendering which holds the pixels for the whole frame cycle, whilst the pixels are only on for a short period during *impulse-type*. This would suggest that it is best to perform tests on motion blur, on a CRT screen.

There does not seem to be any research done to specifically test frame rate and the perception of realism in film, leaving this as an unknown area to investigate. Frame rate for film is generally set at 24fps, but with the recent introduction of High Frame Rate(HFR) films are now being made at 48fps with prospects of using even higher frame rates to increase the clarity of the images. Zinner et al. [2010] look at video streaming applications and the impact of frame rate and resolution on objective quality of experience(QoE) metrics, using the structural similarities(SSIM) and video quality metric(VQM). They conclude that video sequences with lower resolution performed better than the sequences with lower frame rates in terms of the VQM. They also validated that SSIM and VQM could be used to measure the behaviour of different aspects on the QoE.

In an interview with Jen Yamato [2012] from the online movie magazine Movieline, filmmaker James Kerwin comments on the science behind 48fps, and why it is the audience reacts negatively to the high frame rate. Kerwin mentions that the human eye sees the world at 66fps though the brain only perceives 40 instances a second, as such when film reaches 40fps it looks real to us, whereas

24fps or 30fps does not. This apparent realism can makes us loose our suspension of disbelief and at times brings us into the uncanny valley. Cinema is built on conventions that we have come to accept as real in film, even when they are inherently fake in the real world, be this movements or the way people talk. Kerwin discusses how the higher frame rates makes us look through these conventions and see the artifices of the acting. Frame rate is an area of relatively little research in terms of its affect on film viewers, especially since at this point in time only one film has been released at 48fps.

Red Digital Cinema[Red, 2012] explore HFR, coming to a conclusion as to what HFR might hold for the future of visual displays. They highlight the motivations behind HFR, stating that though around 15fps is necessary to provide the illusion of continuous motion, research has shown that 60-80fps increases the clarity and smoothness of the footage. Also HFR makes it easier to extract more precise stills for use in print, as well as diminishing the blur in each image. They also highlight the reduction of eye-strain and fatigue, due to the reduction in flickering, as well as the increase in image brightness. When images are shown at 24fps, with refresh rates of 48-72Hz, the image is shown 2-3 times and if the image is too bright each frame will appear to flicker. As the image is flashed fewer times in HFR, the projection can be brighter without causing the image to flicker. This is especially important for 3D where the projection techniques create dimmer images, due to the need to double the frame rate to show 24fps for each eye.

Armstrong et al. [2008] investigated high frame rates for television, shooting film at 300fps, allowing for easy conversion to 25, 50 and 100fps video, and testing a series of different 25 second sequences. Due to the fact that most displays can only show 60fps, a projector was used that made it possible to show 100fps. Their observations found that higher frame rate improved the portrayal of motion, even at standard definitions. Where before users had felt nauseated by the HDTV with lower frame rates, especially when going from sharp stationary shots to smeared pan shots, there was at 100fps a clarity especially noted during panning shots. This increased the sense of realism, due to the improved sharpness of the image which improved the depth cues. Their conclusion, which is supported by Red Digital[Red, 2012], is that by increasing the frame rate picture quality can be improved. This will help to remove artifacts that are present at 50/60Hz, which is becoming increasingly important with the increase in television screen size.

Douglas Trumbull [2012] has been developing technology that allows adding objects filmed at one frame rate to films shots filled at other frame rates. He talks of the evolution of film from the early silent black and white films shot at 18fps, to 24fps talkies, to colour films, changing the screen format by introducing widescreen, and now the use of 3D. He mentions that film projectors operate at 144fps, meaning that showing a film at 24fps involves projecting each frame several times to avoid flickering. Also with 3D 24fps is inadequate "often results in objectionable blurring and strobing that diminishes or destroys the 3D effect altogether on fast action". Trumbull's research has lead him to state that 60fps is the "most comfortable and compatible", having also filmed at 120fps with a 360-degree[6] shutter which "makes it possible to digitally merge any number of adjacent frames in order to recover the appropriate amount of blur necessary for 24 fps display". He also mentions that higher frame rates are not suitable for all films, but rather those that transport the viewer to another world, such as *Avatar* and George Lucas's *Star Wars* franchise.

This section has gone into more depth with motion blur and frame rate, exploring their connection further and highlighting the direction research has taken with them. The notion that motion blur is a camera fault that we have come to accept as part of cinema, suggests that audiences can also adapt to it not being present. But how often do we notice motion blur when watching a film, and how does it affect our notion of what we are watching. The research has shown that motion blur helps with the perception of speed and can add to the smoothness of the shown images. Many algorithms have been devised to improve the motion blur that is added to scenes where there originally is none. For the animation that will test motion blur I will consider using the cartoon blurs, though only if they remain within the plausible for the animations world. As CRTs are better for showing motion, if possible it would be best to test on one, though this may be difficult due to LCDs being the most common screens. Frame rate has recently become a hot topic because of the release of Peter Jackson's

[6]The films we are accustomed to watching are shot with 160-200-degree shutters, giving the footage the quality we associate with cinema

The Hobbit: An Unexpected Journey(2012) and his use of 48fps. When looking at the research 48fps is very little compared with what is possible to create, though the technology to show higher frame rates is not every day. The research says that 60fps is close to how we perceive the world, suggesting that anything above will not appear any different, whilst we accept cinema at 24-30fps because we can tell subconsciously that it is not natural. If fluid motion is apparent from 15fps it would be interesting to test 15fps or lower to see the lower tolerance of viewers whilst also using standard cinema 24/30fps and going up to 48fps or 60fps and maybe above if the technology is available.

3.2 Visual Perception

To get a better understanding of what we perceive as real on the screen, we need to understand how we perceive things in the real world. Having chosen to focus on motion blur and frame rate, both of which are linked by their connection to motion, I will focus the research on human perception of motion.

To understand how we perceive the world we need to understand how we see the world. Light from our environment enters the eye through the cornea, where after it passes through the lens, which focuses the light, before it finally hits the retina. In the retina we have different photoreceptors that absorb the light and transduce this energy into neural energy. After this the information is sent to our brain, where it deduces what it is we are looking at. This is a simplified version of a complex process that is carefully controlled each step of the way to manage how much light enters the eye. We have three ways of adjusting to different lighting intensities first there is the iris which controls how much light enters the eye through the pupil, then there are different photoreceptors(rods and cones) that react to different lighting conditions, and finally our eyes can throw away excess photons that are not needed. Camera's work much in the same way as the human eye, and the two are often compared, digital cameras being more like the eye than analogue cameras. Both the eye and the camera have an iris/aperture that controls the amount of light entering, a lens that focuses and flips the image onto a photoreceptive surface, this photoreceptive surface is made up of receptors that are sensitive to one of three wavelength groups, in digital cameras RGB(red, green and blue) and in the human eye S-, M- and L-cones(short, medium and long wavelength-sensitive cones)[Wolfe et al., 2009].

Understanding how the eye works, and how the eye and camera compare, is important to understand how they can be, and are, tricked. British Professor of Film Studies MalcomTurvey [2008] states that "a distrust of human vision has played a foundational role in film theory"(pg.99) basing this on the fact that "standard, everyday, normal physical vision is flawed in some crucial respect and therefore cannot be trusted"(pg.101). The notion that our eyes, and in association our brain, cannot be trusted is because they can be tricked by illusions. Optical illusions, or tricks of the eye, can be anything from perspective drawings, where 2D images appear 3D to persistence of vision where an afterimage persists in the retina for less than a second. These illusions are harmless but Turvey felt that due to this distrust in human vision, art should not strive to copy the real world that we see with our eyes, but rather it should redefine itself. Cinema tries to recreate the world through the directors vision, and their vision is based on visual cues that help them perceive the world. We understand the world around us by recognising features, which we then group into objects that we can identify, which then help us make sense of the scene around us. To navigate the world that we see, we use different cues that help us determine such things as size, texture, depth, speed, etc. All these cues help us navigate the world and make sense of what we are seeing. As I decided to focus on motion blur and frame rates, I will be looking at the cues related to perceiving motion and looking at how fast the eye sees.

Scherzer and Ekroll [2012] analyse motion in terms of occlusion. They consider the perception of motion in terms of the occlusion of the background, by a moving object, or occlusion of the moving object by the something in the foreground. Their experiment concludes that motion is perceived as smoother if the spatial gaps between key positions is occluded, or if the gaps themselves are reduced in size. Smith [2010] discusses how the motion we perceive in film is known as apparent motion, because of its origins in static images rather than actual motion, further classifying this motion into long-range and short-range. Long-range motion, such as beta movement, when two objects are alternately shown at different locations ten times a second, giving the perception of fluid movement of a single object. This type of motion requires us to have a knowledge of the real world movement, as well as there being a correspondence between the objects in the sequence. Short-range movement occurs when the displayed images are shown rapidly (greater than 13Hz) show a slight difference in the objects position. This type of motion does not require an understanding of the motion as it stimulates the same system in the brain used to detect real world motion. In cinema most motion is perceived as being short-range motion. This is because film frames are too complex and the frame rate is too high to properly perceive what is happening in terms of long-range motion.

Film is made up of images that are shown in rapid succession, giving the illusion of movement, phi phenomenon[Mov, 2013]. Phi phenomenon, also known as apparent movement, is dependent on persistence of vision, because when the time between the images or lights is less than the visual persistence time, it creates the perception of continuous images or light. Human perception of frame rate is known as flicker fusion. Flicker fusion is when the "rapid fluctuations in brightness; finally, at a certain speed, called the critical fusion frequency, the sensation becomes continuous and the subject is unaware of the alterations"[Hum, 2013]. When there is a lot of light up to 60 flashes a second can be necessary to create a continuous sensation, whilst in darker, night time conditions it can be as low as four. This suggests that the frame rate at which the eye perceives the world is around 60fps in daylight conditions, which is close to the 66fps that Yamato [2012] suggests, where as in darker conditions the frame rate can be as low as four fps. Patrick Mineault [2011] looks at the question of what is the frequency at which humans no longer perceive flicker, reaching the conclusion that flicker fusion occurs at 60Hz, which is also the refresh rate of most screens[Armstrong et al., 2008]. 60Hz is not the same as 60fps, as Hz is the screens refresh rate, though it is possible to show 60fps at 60Hz having one frame per refresh. Showing film at a lower refresh rate will result in a noticeable flicker which can be avoided if each frame is repeated three times, increasing the flicker rate above the critical flicker fusion rate of 60Hz. Another way to avoid visible flicker is to make sure that the perception of light is continuous due to persistence of vision[Smith, 2010].

Frames can be displayed as either progressive scan or as interlaced. Interlaced is where an image is scanned twice, though everything in the image is only scanned once. This is done by splitting a video frame into two fields(odd and even) and having, first all the odd lines shown followed by the even lines. Interlaced was used in CRT displays and by standard television broadcaster services, The fields are shown 50 or 60 fields per second, too fast for our eyes to notice them, corresponding with 25 and 30fps[Tel, 2013]. Interlaced is easier to broad cast than progressive, due to it requiring less bandwidth, and colour quality is slightly better[Andrews, 2011, p. 24]. Progressive scanning is where all the lines of and image are created in sequence and is what is now more commonly used in media. In progressive scanning every field contains the whole picture, thus being able to show full images at 60fps, making motion appear smoother and more realistic[Andrews, 2011, p. 24]. The downside to this method is that it requires more bandwidth, making it harder to broadcast than interlaced. With high definition television(HDTV) taking over the market, it is necessary to decide on a resolution that provides the best image without affecting the cost too much. The lowest high resolution standard is 750progressive (750p), with the next step up being 1080interlaced(1080i), and the highest being 1080p[HDT, 2013]. 750p provides slightly better quality images for scenes containing motion, 1080i generally provides greater detail resulting in cleaner static images, whilst 1080p takes the best of each of the previous resolutions.

This section provides insight into human visual perception as well as some technical aspects related to our perception of motion. Motion in film is created through visual tricks, such as persistence vision, that allow us to see rapidly passing still images as continuous motion. Motion in animation is plagued by flickering if the display speed is under 60Hz, which leads to images being shown multiple times when the frame rate is 23/30fps. Frame rates can be denoted as either interlaced or progressive, where progressive is becoming the norm as it has shown to contain the best results out of the two and holds the most promise for the future. For my test I will be using progressive frame rates, with refresh rates of minimum 60Hz if not higher to avoid flickering.

3.3 Realism and Believability

Having discussed the definition of realism in the pre analysis, this section will go further into depth defining aspects and theories that affect realism, and what makes something believable.

3.3.1 Film and Photography

Since the early days of cinema there has been a debate as to the portrayal of realism in film and how it compares to the realism depicted in photography. Prince [1996a] highlights that this comparison is due to their shared attribute of "being a recording medium". The relevance of looking at this comparison lies in the fact that it brings to light some of the aspects of realism that different theorists have analysed. The comparison tries to answer the question of what makes us believe what we see in a photograph, how this has been translated in to film and how digital media has changed the notion of realism in both.

Mid twentieth century French film critic André Bazin [1974] saw photography as being a medium that "embalms time"[Bazin, 1974, p. 14], capturing a moment in time and immortalising it. To him cinema took this a step further by becoming "objectivity in time"[Bazin, 1974, p. 14], capturing the change in something over time. For Bazin cinema could not escape realism, since cinema, much like photography, is based on "the inalienable realism of that which is shown"[Bazin, 1974, p. 108]. This realism is what helps the viewers ground what they are watching in the real world, because "the screen cannot give us the illusion of this feeling of space without calling on certain natural guarantees"[Bazin, 1974, p. 110].

This comparison of photography and cinema has been linked with American logician Charles S. Peirce's research on semiotics[Burch, 2012]. More specifically his three different types of sign: icon, symbol and index, with the focus being on index signs. When something is an index sign, it is factually connected to its referent. When we look at a photograph, we see everything as it was at the moment it was taken, it is a factual reference to all the objects within its frame. Wollen mentions that Charles S. Peirce considered photographs to be indexical signs and quotes Peirce, saying "Photographs, especially instantaneous photographs, are very instructive, because we know that in certain respects they are exactly like the objects they represent[...]they[...]correspond point by point to nature. In that respect, then, they belong to the second class of signs, those by physical connection."[Wollen, 1998, p. 84]. Also in agreement with the indexcality of photographs is film theorist David Rodowick [2007], who albeit this agreement comments that there is a need to re-evaluate some aspects of the comparison with the advent of CGI, but that "Comparing computer-generated images with film reaffirms that photography's principal powers are those of analogy and indexicality"[Rodowick, 2007, p. 9].

The notion of cinema being closer to indexical signs as well as the comparison with photography is constantly under re-evaluation. Giralt mentions that "neither indexical nor non-indexical images are true representation of reality itself. They are intermediary media between the reality they represent and the viewer" stating as such that images are not reality, but a way for the viewer, through their own interpretation to perceive the reality they are trying to show. Both Wollen and Rodowick suggest there is a need to re-evaluate the comparison of photography and film, as digital film and visual effects makes it harder to tell what is real. As Prince points out "For reasons that are alternately obvious and subtle, digital imaging in its dual modes of image processing and CGI challenges indexically based notions of photographic realism."[Prince, 1996a]. No longer does the image shown on the screen mirror exactly what was filmed, and "visual effects are composites, artificial collages, not camera records of reality"[Prince, 2012]. The notion of effects in films is not new, compositing images together has been done for many decades, but with digital film it has become a larger and more common part of film allowing for seamless additions and removals of given aspects.

Gerry Coulter[Coulter, 2010] founder of the *International Journal of Baudrillard Studies*, analyses French sociologist Jean Baudrillard's theories on cinema, whose ideas opposed Bazin's. Baudrillard firstly considered film to be a degradation of photography and secondly he stood firm against the use of technology in film. In terms of the perception of reality, Baudrillard felt that with the way cinema was evolving there was a "growing blurring between the real and virtual"[Coulter, 2010, p. 10] wherein he saw that there occurred a switch from the real, to the hyperreal. The closer we approach hyperreality in film the harder it becomes to tell what parts of an image are real. As such film is no longer just an indexical sign, representing exactly what is seen, but becoming more of a mixture of all the types of signs that represent aspects of reality that the audience can relate to.

Comparing film with photography and the consequent attribution of semiotics to what is seen, is a way of analysing the reality of what is shown and trying to group it into parts that are easier to analyse. Charles S. Peirce had many theories on signs that were constantly being altered to suit new findings. His three categories of signs can be used to illustrate how realism in film has evolved from analogue to digital cinema, as well as how cinema viewers have evolved with the medium. As an audience we have become accustomed to the unreal, we do not expect what we see on the screen to fully represent what was filmed but we accept it none the less. David Bordwell [1991] in his book on interpreting cinema comes to the conclusion that "certain semantic fields are probably so ingrained that we, and perhaps other cultures, cannot do without them." [Bordwell, 1991, p. 127]. Some semantic fields are so much a part of how we interpret the world, that even across different cultures we can understand each other. Bordwell [1996] uses the term "Cultural Construction" as a way to classify this intercultural understanding. Calling it 'constructed' because humans have created these meanings making them artificial, and 'cultural' because it is not individual, covering a broad social scope. Due to this semantics plays a large part in helping us understand, and get meaning out of, what we see on the big screen. Wollen also supports this idea and concludes that "There is no pure cinema, grounded on a single essence, hermetically sealed from contamination.[...]the cinema has become an almost equal amalgam of the symbolic, the iconic and the indexical."[Wollen, 1998, p. 106]. Photography has also evolved in the digital age, in much the same way as cinema, which is why the two can be compared. Cinema and photography are art forms, and as all art forms they change, they evolve to reflect the needs of their time, in this case photography captures a frozen moment in time, whilst cinema captures the change of these moments over time.

3.3.2 Cinema of Attractions and Suspension of Disbelief

Cinema has since its beginning appealed to our curiosity and our sense of amazement. From the Lumire brothers famous *Train Pulling into a Station*(1896) and Georges Méliès *A Trip to the Moon*(1902) to the age of computer graphics and films such as James Cameron's *Avatar*(2009) and Joss Whedon's *The Avengers*(2012). The films mentioned all amazed audiences by showing them something new, by creating a spectacle out of the unknown.

Tom Gunning, professor in the Department of Cinema and Media Studies at the University of Chicago, coined the term "The Cinema of Attractions"[Gunning, 2006] to describe cinema up to 1906. He described early cinema as being a cinema where "theatrical display dominates over narrative absorption"[Gunning, 2006, p. 384]. In the early twentieth century films directors such as George Méliès played with tricks and illusions to amaze and entertain the spectators, the films narrative taking a back seat. For Gunning the films that were made after 1906 began to focus more on narratives and less on the spectacle, showing cinemas shift into a new era. Senior Lecturer at Kings College London, Michelle Pierson [2002], supports Gunning's Cinema of Attraction, seeing it as a valid theory that highlights how cinema was seen at the time. Pierson offers the explanation that cinema at the time "emphasized the novel capabilities of the new moving pictures technologies rather than their ability either to suggest a story or to represent the world at large."[Pierson, 2002, p. 119]. Once the novelty of cinema wore off more in depth narratives and stories became the next aspect that could maintain the audiences interest in film.

Jae Hyung Ryu [2004] in his PhD dissertation on *The Cinema of Special Effects Attractions and Its Representation of Reality* mentions Gunning's work, concluding that these tricks of attraction are used to awaken the audience from the lull of the narrative. Ryus analysis of Gunnings theory leads him to interpret storytelling as "a mere appendage, serving as a background of cinematic special effects attractions". Ryu's analysis indicates that Gunning's Cinema of Attractions focuses on films where the narrative is only there to provide a link from one visual trick to the next. This is in slight opposition to Pierson, who suggests that Gunning does not think these early films only contained visual effects for the sake of having them, but that they were organised and structured through methods that later would come to dominate narrative cinema. Gunning himself highlighted the importance of maintaining the audiences curiosity through what they are watching, stating that "Rather than being an involvement with narrative action or empathy with character psychology, the cinema of attractions solicits a highly conscious awareness of the film image engaging the viewer's curiosity[Gunning, 1989, p. 121]. He goes on to state that these films do not aim to draw the viewer into the spectacle, the spectator does not get lost in a fictional world and its drama, but remains aware of the act of looking, the excitement of curiosity and its fulfillment. Through a variety of formal means, the images of the cinema of attractions rush forward to meet their viewers." [Gunning, 1989, p. 121]. As such the cinema of attractions does not try to hide the fact that it is a spectacle, but rather highlights this fact and uses it to attract its audience.

Even though Gunning's theory was aimed at films dating before 1907 he acknowledges that the cinema of attractions is becoming prominent once again in Hollywood films, a point also supported by Ryu and Pierson. Gunning [2006] states that "Clearly in some sense recent spectacle cinema has reaffirmed its roots in stimulus and carnival rides, in what might be called the Spielberg-Lucas-Coppola cinema of effects."[Gunning, 2006, p. 387]. This acknowledgment suggests that yet again there has been a change in what the audiences want to see, as well as what technology can provide with, and as he says "every change in film history implies a change in its address to the spectator, and each period constructs its spectator in a new way." [Gunning, 2006, p. 387]. This is true for all forms of entertainment, that must change with the times to fit the needs of the audience.

The audience plays an important role in cinema, and should not be forgotten amidst all the theory. Prince [1996b] notes that theorists often do not test their theories on an audience, suggesting that their theories are flawed due to the significant role of the audience. When experiencing cinema, each individual viewer perceives what they are watching differently, as Prince [1996b] mentions "viewers are behaving quite rationally in using interpersonal cues derived from personal experience to evaluate the behavior of characters on screen. In an important sense, viewers are not being 'positioned' by films. Rather, they are positioning film events and characters according to socially derived, extra-filmic knowledge of appropriate and inappropriate real-world behavior."[Prince, 1996b, p. 82]. This view is backed up by Charles Musser [2006] who analyzes the effects of early films on the audience "Early films often elicited much more than astonishment - They mobilized the sophisticated viewing habits of spectators who already possessed a fluency in the realms of visual, literary and theatrical culture."[Musser, 2006, (p. 176]. As such theory should be grounded in an audience based approach that can establish a norm for viewers with a certain similar culture.

One can ask what is it that makes us watch something even though it is perceived as unbelievable. In the eighteen hundreds, poet and aesthetic philosopher Samuel Taylor Coleridge coined the term; *Suspension of Disbelief*. This term is used to describe how the audience can suspend their judgement of a work and accept what they are seeing without being critical. There are many ways in which to get an audience to suspend their disbelief and there are also many ways in which to jar them back to reality, breaking their focus and enjoyment of the spectacle. In early cinema the audience was presented with new sights, learning to adjust to moving images, which one would think might jar them, but Gunning [1989] thought differently. In his article *An Aesthetic of Astonishment: Early film and the (In)Credulous Spectator* he writes that "the sudden transformation from still image to moving illusion startled audiences[...]Far from being placed outside a suspension of disbelief, the presentation acts out the contradictory stages of involvement with the images[...]a vacillation between belief and incredulity"[Gunning, 1989, p. 119]. This highlights a careful balance needed to maintain the suspension of disbelief, by presenting the audience with something that seems too incredible to be true and then providing a framework within which it becomes credible. Ryu [2007] supports this claim in modern day cinema, stating that Due to the fact that the spectacle of the digital effects is too dazzling and plausible, the viewers suspend their disbelief. However, this moment of suspension of disbelief is the moment of distortion of the viewers perception of reality.

Film is used to incite our curiosity to attract us, and has done so from its initial conception, thus it is valid to call it the *Cinema of Attractions*. Cinema does not only attract us by its imagery, but it can also provoke us, and with each generation new viewers demand new experiences. When creating theories on cinema and film, theorists should always take the audience into consideration, as their responses to films are what control the future of cinema. Suspension of disbelief is what allows us to accept the incredible as credible, even if only for a short while. It allows us to accept monsters and magic that are not real in our everyday lives, so long as they do not contrast drastically with the rest of the film. With the advent of digital-effects it has become easier to create believable creatures and worlds that do not exist, but also with this advance in technology come some pitfalls where digital artists must be wary. There is the *Uncanny Valley*[7], which explains the discomfort when watching Robert Zemeckis *Beowulf*(2007) and *The Polar Express*(2004) where motion capture was used to create the characters. The issue with *The Polar Express* was that the characters had lifeless eyes, whilst in *Beowulf* even though the amount of detail in creating the characters had increased, the characters still lacked the full repertoire of expressive behaviors[Prince, 2012, p. 125]. These are just some examples of how character animation can go wrong, but there are also other pitfalls such as badly lit or textured three dimensional models or badly composited images where the backgrounds do not fit the foreground.

This section has further highlighted the individuality of realism, and how little is required to topple this perception. Cinema is an art form, an attraction, and like any art form it goes through periods with different styles that audiences adapt to and accept as reality. To help with the perception of realism it is necessary to include some signs that make it possible for the audience to ground what they are watching. By being able to find some correlations between the real world and the cinematic universe it helps the audience suspend their disbelief. Care should be taking when trying to recreate realism, as there is always the fear of entering the uncanny valley. This is mostly problematic when creating humanoid characters, as we are very aware when something is very close to appearing real but fails on some aspect. Testing realism will be tricky, as it is based on personal opinion, though structuring the test to allow for personal opinion should get around this problem. The animation that will test motion blur and frame rate should be made in one style and should contain references to the real world so the audience can relate to what they are watching.

3.4 Experimental Methodology

In this section I will look at how to test my final problem statement, focusing on different methods to be used for triangulation. The methods explored include questionnaires, interviews, observations, eye tracking and, statistical and qualitative methods.

As I will be testing PCR which is based on personal opinions a questionnaire is a logical, anonymous and not too invasive way to get the test participants opinions. Questionnaires can be built up with open and or closed questionsJensen and Knudsen [2006], depending on the type of data that best answers the problem statement. Open questions, often used in qualitative questionnaires or interviews, do not provide the respondent with any answer choices, allowing the respondent to express their own opinion and explain the answers in their own words. This allows for a greater variety in the answers as it has not been predefined, though this also means the data can become too varied and difficult to analyse. Open question answers can suffer when they have to be typed up, analysed and categorised in the analysis phase, thus open questions are rarely used in quantitative questionnaires. Closed questions, or quantitative questionnaires, make it easier to ensure easily categorised answers, as they tend to provide the respondent with different choices for answers. For closed question, quantitative questionnaires, the questions are commonly multiply choice or ratings on a scale. For this project a questionnaire with mostly quantitative questions will be most beneficial due to the abstract nature of realism, and a need to define the term in order to analyse the results.

Deacon et al. [1999]pg.71 discusses how, both open and closed questions, can be grouped under four different categories, that are initially outlined by Don Dilman(1978), these categories are: Behaviours, beliefs, attitudes and attributes. Behaviour asks about what people do, beliefs ask about what people believe in, attitudes are about preferences and attributes ask about background information. As this experiment will focus on what people think and will require some background information about the test participants, I will focus on looking at beliefs and attributes. When ques-

[7]a term coined by robotics professor Masahiro Mori in 1970, for the dip in believability that occurs when creating humanoid characters, where the creators must be careful of not alienating the audience by creating something that is so close to human in appearance and behaviour, but essentially falls short on some level creating a sense of revulsion in the audience

tioning about a persons' beliefs and attitudes, according to Deacon et al., care should be taken with the phrasing of the questions as this might influence the way the test participant answers. It is also a good ideas to ask questions related to a topic that help establish to what degree they believe in something. Attributes are questions that help to classify the results, such as age, gender, occupation, etc. These questions, according to Deacon et al., should be placed near the end of a questionnaire as test participants feel more assured about the integrity of the research.

When creating a quantitative questionnaire, there are many different types of questions that can be used, and methods to analyse them. For this experiment it will be most pertinent to use a scale, where on the users can determine their opinion and the results can easily be analysed later. Some examples of scales are: rating scale, the Visual Analogue Scale(VAS), semantic differential scale, stapel scale and the Likert scale. Rating scales are used to voice an opinion of how much the test participant likes or dislikes something, usually on a scale from one to ten, or in some cases up to one hundred. A VAS scale is used for subjective characteristics that are hard to set a numerical value on, by asking participants to indicate a position between two points that indicates their agreement or disagreement. The semantic differential scale requires that participants rate on a seven point scale whether something is more inclined towards one attribute or another, such as good or evil. The Stapel Scale is a unipolar scale ranging from minus five to plus five and does not have a neutral point, it is analysed in the same way as a Semantic differential scale. The Likert scale asks participants to rate on a scale, customarily from one to five, how much they agree or disagree with a given statement. In the context of this report a Likert scale or simple rating scale would provide adequate answers, while a VAS scale may provide the participants with too much choice and the semantic differential and Stapel scale require the participants to rate attributes which is not necessary.

When designing questions that are to be rated on a scale it is necessary to mix with both positive and negative statements, as participants are reluctant to be critical[Travis, 2009]. These scales are often used when testing desirability, satisfaction or engagement[Mic, 2002], and considering that realism is also an abstract term, similar methods can be used when analysing it. As PCR is being tested it is necessary to ask how real the participants found the clips they are watching, as well as asking questions about aspects that relate to realism. The questions related to realism can be used to create a PCR response rating which will support whether the participants did find the clips realistic.

Having looked at quantitative methods I will now present some qualitative methods that could be used when testing PCR. There are many different ways to perform qualitative research, these include, but are not limited to, different types of interviews, long answer questionnaires and observations. Interviews are good, though again testers may have difficulty coming with negative feedback, this may also plague long answer questions. When having the test participants answer long answer questions their responses can come with varying degrees of detail. Depending on the type of questions asked, it is sometimes possible to take key words out of participant responses and create a word cloud or weighted list, where it is possible to see what are the most common words used by the respondents.

Observations are good as a way recording a test persons physical, and verbal responses during testing[Jordan and Herderson, 1995, Pink, 2007]. Observations of test participants can be made with varying degrees of involvement of the researcher and in either controlled laboratory experiments or through field studies. For the purpose of testing PCR it would be best to conduct the test in a laboratory environment, as the aspect being observed is their reaction to different frame rates and motion blur in a short animation clip, not needing to observe the participants daily routine. The observer can be passive or active, seated in the room or out of it depending on how much interaction is desired with the test participant. In this project as little interaction with the test participant is desired, so as to minimise the observers impact on the participants answers. This does not mean that the observer needs to be seated outside of the room, as there may be some doubts about the questions or what they should do, so the researcher need only be seated out of sight. While observing video and audio recordings can be used to record what is happening, as well as getting different angles on the same scene. If the test participant is seated watching a computer screen, so as not to distract them by having the observer seated in front of them, a camera could film their face. While the camera films from the front another camera could be placed behind or the observer could be seated behind taking note of what is being said and when.

Having gathered video observations, they also need to be analysed, and as it is up to the test participant to what they are watching, each recording can be very different from the next. Finding foci for the analysis of the video recorded data is important, as it structures the analysis by providing points to look for in the video recordings[Jordan and Herderson, 1995]. The different foci that Jordan and Herderson indicate can be used for video analysis are as follows: the structure of events, the temporal organization of activity, turn taking, participation structures, trouble and repair, the spatial organisation of activity and artefacts and documents. Not all these points are valid to the analysis of test participants watching short animation clips, as they deal with various participants interacting with each other and with other artefacts, but they provide a guideline. Structure of events looks at the passage of time in terms of highlights and shifts in activity, which can be used to see how the users attitude changes from clip to clip. The temporal organisation of activity looks at the rhythm of what is happening to see if there are any breaks in rhythm that cause the viewer frustration. This is a foci that is not very relevant to this project, unless it is the time they take to answer the questionnaire, as a video has a specific run time that cannot be altered unless there are technical issues. Turn taking is only relevant if two or more people are taking the test where it can be observed if one person takes the lead or talks more than others. Participation structures looks at how people group and if a hierarchy forms, which is only relevant if there is more than one person being tested. Trouble and repair is, as the name suggests, how problems are tackled and is only relevant if there are technical issues or problems with the questions in the questionnaire. Spatial organisation looks at how people occupy space and their body language, which is going yield limited information if the participants only have to sit and watch short animation clips. Artefacts and documents looks at how the participants interact with technology, in this case, a computer or paper. In the experimental design I will highlight in more detail which foci will be used and how.

Another way to observe the test participant is to find out precisely what they are look on the screen. Eye tracking is a good method to get an idea of what is attracting the viewers gaze whilst watching something on a screen. The hardware requirements for eye tracking are relatively simple, needing a camera or web-camera as well as infrared(IR) light. The camera should have a resolution of 640x480 at 25fps, and should be placed close to the eye, unless it is able to zoom. An infrared camera would be optimal for this, but a normal web camera could also be used so long as the IR filter is removed. IR is used as it makes the eye easier to track by the software. There is open source software available online that is relatively easy to use[8]. The issue with eye tracking is that the data takes a lot of time to analyse especially as the image is constantly changing. This method can yield a good insight into what the user looks at, at different frame rates and with motion blur, but requires that there is enough time to analyse the results afterwards.

In order to properly analyse any qualitative results gathered some statistical methods will now be explained. The first calculation to be done with the data is to find the mean average, as this will establish a single value for all the data in that category. The second calculation to be performed is the standard deviation of the data, to determine the spread of the data. The more spread out the data the less consistent the responses. Having found a mean for the different questions, it would be pertinent to use a T-test to find whether the means of two groups are statistically different from each other. If there are many groups an Analysis of variance (ANOVA) test can be performed, as it generalises the t-test results, to look for significance in two or more variables. If there is no statistical significance between the results of the ANOVA test or t-test, meaning that the p value is greater the 0.05, then the null hypothesis cannot be disregarded. Other statistical methods that can be used to find any connections between the data are Pearson Correlation Coefficient(PCC), which looks at the linear correlation between two variables, and regression which also looks at the relationship between variables.

A final point to consider is population sampling. Getting an appropriate sample of the population reflects a truer image of the populations tendencies and makes it easier to draw conclusions on the data. The population can be sampled through probability sampling and non-probability sampling. Probability sampling can further be divided into simple random sampling, systematic sampling and

[8]A group from ITU Copenhagen who are working on gaze tracking and have made their software open source and available to all, so long as you cite one of their papers, via their website: http://www.gazegroup.org/

cluster sampling. Simple random sampling is where all have an equal chance of being selected with no order and each participant is selected independently. Systematic sampling randomly selects elements within a sampling frame, taking every nth element. Cluster sampling occurs in stages where first groups of elements are chosen and then individuals are selected from within each group. Non-probability sampling is based on the availability of the individuals, as they have volunteered, or because the researcher deems them representative of the group being tested. Each sampling method has its advantages and disadvantages which should be taken into account when choosing one.

From this research it has been determined that a questionnaire will be used containing mostly quantitative questions, but not discarding the likelihood of there being some quantitative questions. Observation is a useful method of gathering extra information about the user while they are testing and can be backed up with notes taken by the observer as well as an interview, though it is most likely that an interview will not yield any criticism. The observed data can be analysed by using the different foci presented by Jordan and Herderson [1995]so that there are different aspects to look for. Eye tracking will provide an interesting insight into what the user notices while looking at screen, though it should only be used if there is plenty of time to analyse the results. There are many different statistical methods that can be used to find correlations amongst the gathered data, to the final structure of the questionnaire will determine which ones are the most appropriate.

4 Experimental Design

This section will present a method of testing my final problem statement. I will explain my hypotheses and success criteria that will be used to analyse the results in the discussion section of this report. I will also suggest a test set up based on the test methods and variables to ensure that all test persons receive a similar experience. Finally I will look at the requirements specifications that will determine what is necessary to create the product that will be tested, as well as the target group demographics.

4.1 Hypothesis and Success Criteria

To test whether the experiment is a success I have created the following success criteria, that states that at some point the viewer perceives what they are watching as being cinematographically realistic, and that there is a more noticeable difference between the clips when watched without motion blur. Based on the research I have created the following hypotheses:

1. The higher the frame rate, the more realistic the images will be perceived as being, while at lower frame rates the images will be perceived as being less realistic.
2. With the inclusion of motion blur there will be less of a noticeable difference between the frame rates. With the test participants not as often noticing a difference between the clips.
3. The higher the frame rate, the faster the car will be perceived to be going.
4. The test containing motion blur will increase the perceived speed of the car.

The null hypothesis that will counterbalance the above hypothesis are as follows:

1. There will be no difference in the perception of realism between the frame rates.
2. Motion blur will not change the perceived difference between the frame rates.
3. The frame rate will not alter the perception of the cars speed.
4. Motion blur will not affect the perception of the cars speed compared to the test without motion blur.

These hypotheses will be evaluated during the discussion of the test results so long as the single success criteria, that what they are watching is at some point perceived as realistic, is full filled.

4.2 Test Method

In the test methodology section I looked at various methods that could be used to test the users PCR of frame rate and motion blur. Based on that research I found that a method of triangulation involving questionnaires, observations and gaze tracking would provide optimum feedback. Unfortunately due to time constraints and lack of equipment eye tracking will not be used for the test in this report.

The test will be run on one to two people at a time, with the test participants only watching each clip once. The test participants will test one of two groups, where the difference is whether the clips do or do not contain motion blur. Each group contains three clips which differ in their frame rate. The results from each group will be looked at internally, how frame rate is affected within the group, as well as looking across the groups to see how motion blur affects the results.

The test participants will not be told what the test is about, being that they will be watching three clips and answering one page of the questionnaire after each clip, with the questionnaire ending with some general questions. This information will also be available at the beginning of the questionnaire. Most of the points on the questionnaire will be formulated as likert items or rating scales as well as some yes no questions, with only one final general questions being a more open qualitative questions. At the top of the questionnaire a definition of PCR will be presented to explain what is meant by the use of the term realism or believability. A further in depth explanation of the questions will be presented later in this section, the actual questionnaire can be found in the Appendix A.

To support the questionnaire, the test participants will be filmed by a camera placed so that it captures their facial expressions. The test participants will be told that they can think aloud, even if there is only one person participation, if there is anything that strikes them about what they are watching. The researcher will also be in the room, seated behind the test person so they are not distracted, taking notes of what the test person may say or do and note down what is happening on the screen to produce these reactions. Afterwards the film will be transposed and analysed together with the observers notes to determine what, if anything, caused a reaction in the viewer. The foci for the analysis of the video will be presented later in this section.

4.2.1 Test Variables

Variables will be defined so that the test to runs smoothly for all participants. These variables will control the cause and effect of the experiment as well as the test set up. The observed variables will be the independent, manipulated by the researcher independently of the test person, and the dependent, measured behaviour hypothesised to be caused by the independent variable.

The dependent variables for this test will be the PCR for each test participant based on their responses in the questionnaire as well as any verbal communication during the test that is recorded by the camera. They will be asked directly if they felt the clip was cinematographically real, as well as being asked some indirect questions based on what helps viewer perception of realism in film.

The independent variables that will be manipulated during this test are the frame rates, within group, and motion blur, between groups. There will be two groups, one with motion blur and one without, whilst within the groups there will be three clips each showing the same animation at different frame rates. The frame rates that will be used are 24fps, representing present film frame rates, 48fps, which is the higher frame rate that is being experimented with in cinema at the moment, and 60fps which is being considered as a standard for all future films. The order in which they are shown the frame rates will be chosen randomly before the start of each test to ensure that the order does not affect the results.

The controlled variables in the test will remain the same for each participant. The animation used is the same one under all the conditions. The test participants will watch the animation on the same Windows laptop, wearing headphones to minimise external distractions. All the tests will occur in the same, or a similar, room under the same lighting conditions. There will be an even number of test participants so that equally many test each group. The questionnaire used will be the same for all test participants, as will the information they are given prior to the test. The set up with the camera and researcher will be the same to ensure that the observed results remain consistent.

4.2.2 The Questionnaire and Observation Foci

Here the questionnaire will be outlined and which statistical methods I will use to analyse that data, as well as the foci that will be used to analyse the observed and video recorded data.

The questionnaire will contain a series of statements where the test participants can rate from strongly disagree to strongly agree on a five point Likert scale. These statements will be used to determine how realistic the user found the short animation clip that they are shown. The first statement will straight out ask if they found the clip cinematographically realistic. The statements that come after this will be linked with realism, in an attempt to ascertain the level of realism. These statements will be based on the other aspects that were researched to be important for the perception of realism in computer generated imagery. These aspects were camera and object movement, texturing, lighting, shadows and level of detail. The statements will not directly ask about these aspects as that may make the them too technical and specific for people who do not have a background in computer graphics. As such detail can be assessed by asking if the scene was too confusing, if the car was an integrated part of the scene, or if the camera movements were too distracting. Asking whether it is easy to guess the outcome of the action in the clip, helps to determine if the participants understand the rules within the animations world, which means that the actions and reactions are realistic within the given environment.

There will also be some questions where the user is asked to rate on a ten point scale. These questions will be the pertaining to speed and the quality of the clip they are watching. I chose a ten point scale for these two questions because it is easier to judge speed in increments between one and ten and most film rating is done on a scale from one to ten or one hundred[9]. I will be asking about the perceived speed of the car, as this is reported to be affected by both motion blur and frame rate. By getting the test participants to rate the quality of the clip, they are determining how believable they found the clip as a whole, which is linked to realism. The final section of the questionnaire will ask whether the test participants noticed any differences between the clips, and if they did they will be asked to write down what these differences were. After this they will fill in their age and gender and be asked a few yes no questions as to whether they have any knowledge of computer graphics or consider themselves film enthusiasts. The final question will be whether they saw *The Hobbit: An Unexpected Journey* in 3D at 48fps, since this question may give away to some that the difference between the clips has something to do with the frame rate.

The data gathered through the questionnaire will be analysed both in group and across groups to look at how frame rate within group affects the perception of realism, and how motion blur between groups alters this perception. The statistical methods used will determine what, if anything, affects the perception of realism in different clips by trying to find correlations between the data. Within the individual data sets the mean average answer will be found, and standard deviation will be used to find out how spread out the data is. ANOVA, and or T'-tests, will be performed to try and find the significance between two or more of the test variables. Whilst Pearson's Product Moment Correlation Coefficient and Regression will be used to further analyse if there is any relationship between the variables.

The foci that will be used to analyse the observed and video recorded data are as follows. The observer will note down anything that is said during the test to make it easier to locate, as well as noting if nothing was said, indication that those films do not need to be reviewed for audio samples. All the filmed data will be analysed to see how the participants facially react to the different clips, as this cannot be seen by the observer. Following the foci outlined by Jordan and Herderson, the clips will be analysed in terms of the structure of events, if more than one person is being tested participant structure can be noted, spatial organisation and artefacts and documents. Structure of events will cover what happens as the test participant performs the test, looking for any changes in behaviour as they watch the different clips. If more than one person is participating in the test it is relevant to know who, if any, takes charge of the experiment and who speaks the most, as this might influence the others answers to the questionnaire. Spatial organisation will look at the test participants body language while watching the clips focusing on whether they are alert and upright or bored and slouched. Artefacts and documents will note how they handle the video clip and questionnaire and if they had and difficulties with either.

4.2.3 Test Setup

The set up for the test will remain the same for all the test participants to minimise outside bias. The test will occur in a room where the lights are turned off to diminish any light reflections on the viewing screen, but the blinds will not be pulled so that the camera is able to record distinguishable expressions and movement. The test will be run on a laptop screen that has a refresh rate of 60Hz, the videos will be shown in VLC and the questionnaire will be answered online with the results being made available to the researcher in Google spreadsheets.

The camera will be placed in front of the test person, whilst the researcher will be seated behind and slightly to the side, so as not to distract the test participant but still be able to see the screen. The final set up can be seen in figure 1 below.

[9]The internet movie database (www.imdb.com) rates films on a scale from one to ten, while metacritic.com gives films a rating out of one hundred

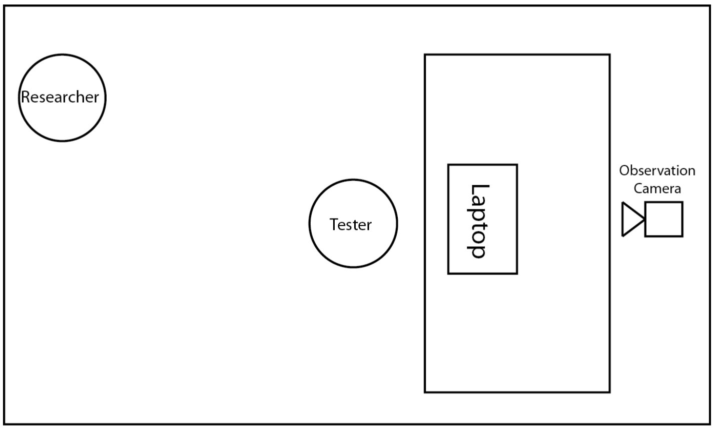

Figure 1: Diagram of the test set up

4.3 Hardware and Software Requirements

For the creation of this test, the following software and hardware requirements must be met. To create the animation clip any 3D modelling software could be used that allows for the manipulation of frame rate. Autodesk Maya 2014 is an appropriate program to use as it is capable of modelling, UV-texturing, animation and rendering. To play the animation, any media player can be used.

To show the higher frame rates a screen or projector capable of a refresh rate of at least 60Hz is necessary, though higher would be preferable. Most computer screens have a refresh rate of 60Hz, with projectors and newer television screens going up to at least 120Hz, some even going up over 200Hz. To run Autodesk Maya 2014 the computer should have a 64-bit intel or AMD multi-core processor and a minimum of 4GB of RAM.

4.4 Target Group Demographics

This test is aimed at both men and women aged 18 and up, to avoid parental consensus. The test persons should have normal to corrected-to-normal vision, as abnormal vision might influence the results if they cannot see the animation properly. They should also preferably not be colour blind though it should not affect the results of the experiment. The test participants will also be asked whether they have any background in computer graphics, or are film enthusiasts, to determine whether this will have any effect on their PCR, and whether this makes them more likely to notice the difference.

5 Design and Implementation

This section will focus on the design and implementation of the animation at different frame rates and with or without motion blur. In order to test frame rates and motion blur, an animation needed to be created that would allow for motion blur to ordinarily be significantly present, and to highlight what happens at different frame rates.

We often associate motion blur with high speed, which is also supported by the research, that suggests that the more blur the greater the speed. Due to this, situations that included speed were brainstormed, and the following suggestions arose: different sports, falling objects, different transportation modes, and racing. I decided that the most interesting situation would be racing. Initially I thought of creating two cars and have them race each other, but the animation of the two cars would be time consuming as well as increase the render time. Below, in figure 2 are my initial sketches of the car.

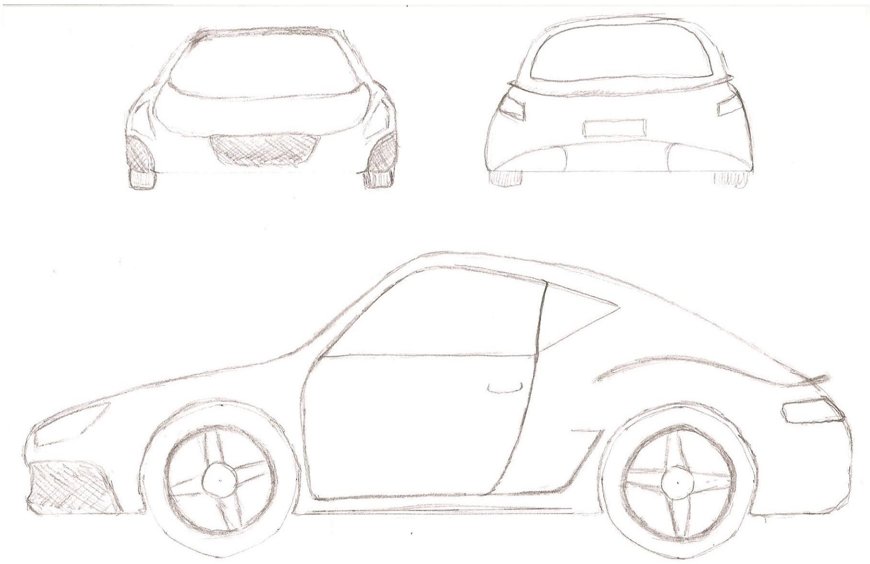

Figure 2: Sketches of the Car

I decided the car was going to be a toy car, and as such it was okay if I tinted the glass so that the inside is invisible and if the head- and taillights looked like stickers. These small touches helped to keep the polygon count down and decreased the animation requirements of the car. The only aspect of the car that I animated was the wheels, which I edited to turn around whenever the car moved forwards on its x-axis. Figure 3, seen below, shows screen shots of the final model.

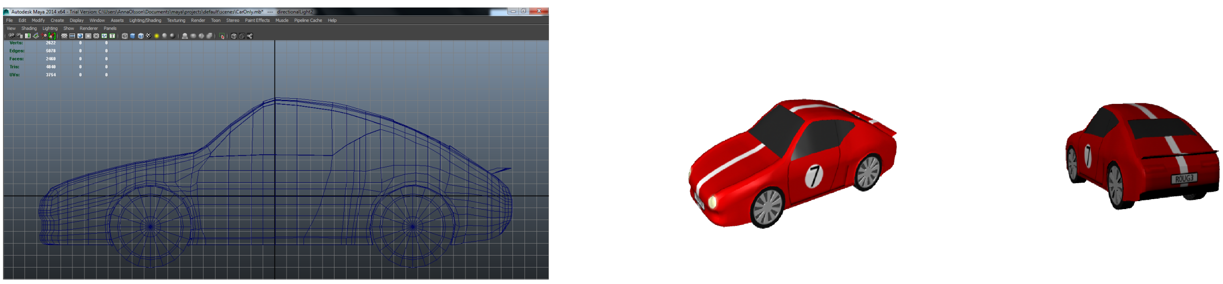

Figure 3: The car wireframe as well as renderings of the Car

When it came to animating the car in an environment, there were many possibilities for scenarios where a toy car could be used. I decided that to create some dynamics in the animation I wanted to have the car jump, and or fall, from something. I tried various ways of animating the car, starting with key-framing its motions by hand, which did not make the animation look real, especially when it came to the physics when the car was falling. I then tried using Autodesk Mayas own dynamics system which gave the car realistic physics based motion, but it could not be controlled. Finally I made the car follow a motion path, which provided smooth motion, though jumps and falls had to be tweaked by hand. At first I worked on a ten to fifteen second animation, where the car went down one ramp on a table and up another to be sent flying across the room ending with it hitting the wall and falling to the floor. This animation was used to see how the different animation methods for the car worked, knowing that the final animation would have to be longer. I ended up using what I had created as the initial part of the longer animation, making the car land on the ground safely after flying through the air, rather than have it hit the wall. After landing on the ground, the car would then slalom around, under and over objects in the room to increase the action in the clip, finishing the clip once again on top of a table.

Using a motion path made it easier to steer the car, but for the final seconds of the animation I wanted to use Maya Dynamics to make the car fall off the table where it stops precariously on the edge. This forced me to open a new identical project where I could unlink the motion path to allow the physics to work on the car, because in Autodesk Maya motion paths do not react to physics and neither motion paths nor rigid bodies can be key-framed. The final seconds of the animation that require the car to tilt and fall of a table, were created in a separate document, but rendered as a continuation of the rest of the animation, so as to be easily put together with the rest. I ended up discarding these final seconds as Maya showed me one thing but rendered another, and I did not have time to figure out the reason for this. This resulted in the animation ending with a shot where it appears the car is not being supported by the table, when in fact it is barely being supported.

The scene the car travels around in was designed as a; wood work room and paint work room. I did not want to add too much that would increase the polygon count, but I needed some objects that the car could interact with. I tried to keep it to simpler objects that might be found in a handcrafts work room, as well as other objects that could logically create some dynamics for the car. I mainly relied on texture to add detail to the objects in the room, creating all the textures from a mixture of photographs and Adobe Photoshop brushes. I also wanted the textures to have discernible details, since higher frame rates supposedly make backgrounds clearer. Figure 4 shows a render of the final appearance of the room.

Figure 4: A Rendering of the room wherein the animation

Due to the fact that, the more light sources in a scene the greater the render time, I initially only wanted to have one light source. As the room became bigger to accommodate for the prolonged animation I needed to add an extra light source in order to see the action. I created two point lights, and added a ceiling lamp cover model over them to disguise the light sources. I tried to use point lights as they provide a greater freedom when it comes to manipulating shadows, but they left the ceiling in complete darkness, and no solution was found for this issue.

Having modelled all the aspects for the scene that I needed, and having animated the car and camera to 24fps, I now needed to increase the frame rate. Maya has an inbuilt setting that allows you to choose how many frames per second you want your animation to be at, modifying any existing animation to fit the new frame rate. Going from 24fps to 48fps was easy, as it only required doubling the number of frames in the animation, whilst going from 24fps to 60fps meant that it had to increase the number of frames by 2.5. This meant that there were half steps in the animation which had to be fixed by hand. It was only after animating the scene that I realised that Maya had also added key frames between the camera translations, meaning that there was some funny two to three frame camera work. I mostly solved this by going into Maya and removing the frames between the camera transitions, and adding the frames so that the camera movements occurred at the right times.

Having the three different versions of the scene, I needed to render the scene. I chose to use Mental Ray, as it could provide the best results for what I was creating. I batch rendered the scene as individual .jpg images, so that I could easily stop the render process if things went wrong, without losing what had already been done. I rendered the images at 720p as this was the only high definition format that the editing software, used to link the images in sequence, could render in up to 60fps. I also added motion blur through Mental Ray in Maya, which works by altering the shutter angle. I kept the settings at one, as setting them higher made the scene unrecognisable, due to both the camera moving and the car moving. Figure 5 shows the same frame with and without motion blur. Adobe After Effects was used to link the images together, playing them at the intended speed, and exporting the finished clip.

Figure 5: A Rendered frame from the animation, on the left without motion blur, on the left with motion blur

6 Test and Results

This section will present the results of the test on different frame rates with or without motion blur. In total 60 people participated in the test, selected on the basis of availability, 30 participants tested the three clips with motion blur, and 30 tested without motion blur. Out of the 60 test participants 48 were male and 12 were female, six women in each group. Participants ages ranged from 18 to 29, with two not providing an age, the average age being 22.5.

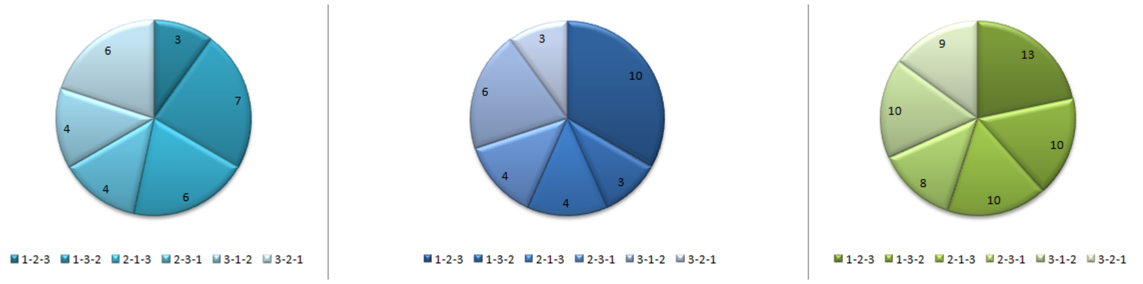

Figure 6: These three graphs show how many test participants tested each order for the clips. The chart on the left represents the tests without motion blur, the chart in the middle represents with motion blur, and on the right is the pie chart showing the sum of the two tests.

Out of the 60 test participants 22 tested individually and 38 tested in pairs. The test participants viewed the animation clips in one of six orders, this was chosen randomly for each test resulting in uneven numbers testing each sequence. The number of test participants to test each clip sequence can be seen in the pie charts in figure 6.

Figure 7: One question asked if the test participants had seen *The Hobbit: An Unexpected Journey* in 48fps, for those who answered yes, they were asked for their thoughts on the higher frame rate. This figure is a word cloud of the answer to that question.

Out of the 60 test participants 35 had a background in computer graphics and 40 considered themselves to be movie enthusiasts, with only 24 having seen *The Hobbit: An Unexpected Journey* in 48fps. As shown through the word cloud in figure 7, the opinions on the higher frame rate in *The Hobbit: An Unexpected Journey* are mixed. Some of the participants liked the higher frame rate and found it made the 3D better, whilst others found it more confusing and made it harder to perceive details. There were also some who did not have any opinion not having noted any differences to the regular 3D.

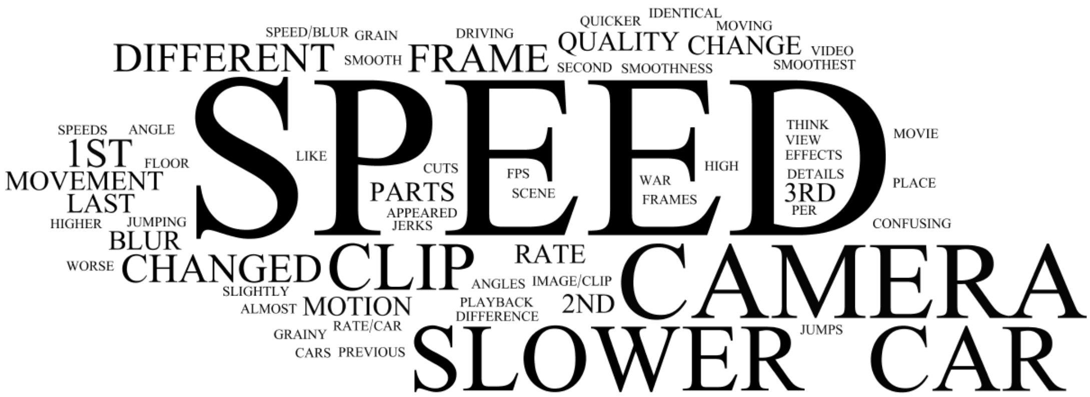

Figure 8: A word cloud of the answers to what the test participants, who tested the slips with motion blur, perceived as being the difference between the clips.

The results of the test show that out of the 60 participants, only eight, four in each group, did not notice any different between the clips. Those that did notice differences between the clips named speed changes as being the primary difference in both groups as shown by figure 9 and 8. The speed changes were commonly attributed to both the car and the camera, as can be seen by the common occurrence of both words in the word clouds. It should be noted that in the clip without motion blur the car was mentioned more often than the camera (figure 9).

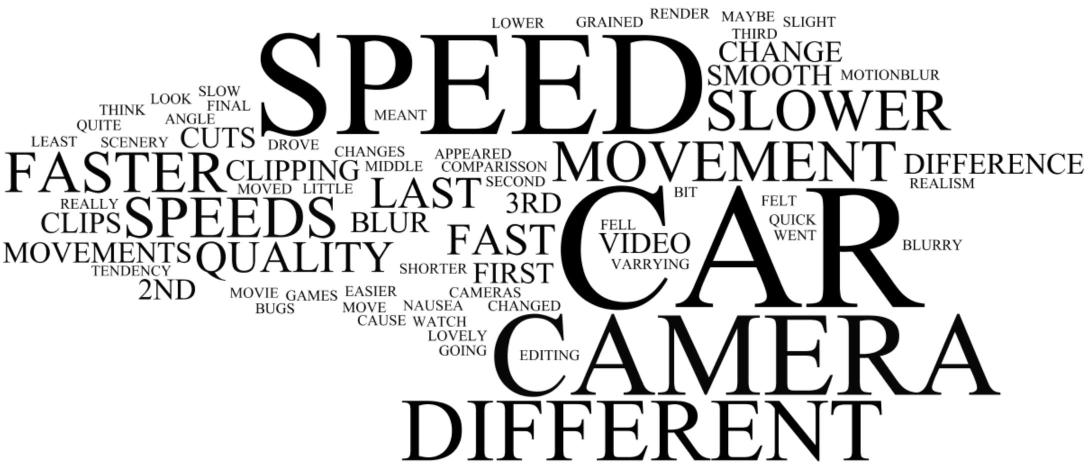

Figure 9: A word cloud of the answer to what the test participants, who tested the clip without motion blur, perceived as being the difference between the clips

The test participants were asked to rate from one to ten, their perception of the speed of the car. For the clips with motion blur the average speeds were, for 24fps 4.5($\pm$2.24), for 48fps 4.5($\pm$1.68) and for 60fps 4.13($\pm$1.91). For the clips without motion blur the average of the results were for 24fps4.17($\pm$1.06), for 48fps 4.77($\mp$.59) and for 60fps 4.23($\pm$1.79). The average of all the results, at the different frame rates from 24fps to 60fps, is 4.33($\pm$2.39), 4.63($\pm$1.62) and 4.18($\pm$1.84). These results can be seen in the table 1. From these results it can be seen that the car was perceived as going the fastest at 48fps, and generally perceived to be going the slowest at 60fps. With motion blur the mean perceived speed of the car was the same for 24fps and 48fps, though the standard deviation of the data suggests that the data was more spread at 24fps than at 48fps. Without motion blur the mean perceived speed of the car was closest between 24fps and 60fps. The mean difference between the perceived speed of the car was smallest with motion blur, the mean difference being 0.24 contra

Perceived Speed of the Car			
Frame Rate	With Motion Blur	Without Motion Blur	General Average
$24fps$	4.5(±2.24)	4.17(±1.06)	4.33(±2.39)
$48fps$	4.5(±1.68)	4.77(±1.59)	4.63(±1.62)
$60fps$	4.13(±1.91)	4.23(±1.79)	4.18(±1.84)

Table 1: Table showing the mean averages of the perceived speed of the car at the different frame rates in the clips with and without motion blur as well as an general average for each frame rate, the standard deviations are in the brackets.

0.4 in difference of the test without motion blur.

An ANOVA test, with a 5% significance, was performed on the perceived test results to find any significant variance in the data. The ANOVA results were F(3.9) = 0.40 , p = 0.53 amongst the samples, F(3.05) = 0.79 , p = 0.43 amongst the columns and F(3.05) = 0.06 , p = 0.94. The samples ANOVA result represent with motion blur and without motion blur, the columns result represent the different frame rates, and the interaction result looks at the interactions between frame rate and motion blur. The ANOVA test on the perceived speed yielded that there is no significant difference between the results.

The perceived realism of the clip was measured in three ways. The first was by asking the test participants to directly rate the perceived cinematographic realism of the clip based on a likert scale going from one, strongly disagree, to five, strongly agree. After directly asking about realism, the test participants rated seven statements, also on a five point likert scale, where after an average answer was found for the seven statements, making, what will be referred to as, a realism rating. The third statement that would test the realism of the clips was a rating, from one to ten, of the quality of the clips. The results for each of the three realism statements can be seen in figure 10

Measures of Realism	**With Motion Blur**			**Without Motion Blur**			**General Average**		
	24fps	*48fps*	*60fps*	*24fps*	*48fps*	*60fps*	*24fps*	*48fps*	*60fps*
PCR of Clip	**2.83**(±1.05)	3.20(±1.03)	3.30(±1.09)	3.40(±0.66)	3.27(±1.20)	3.33(±1.18)	3.12(±0.86)	3.24(±1.12)	3.16(±1.14)
Realism Rating	3.71(±0.35)	**4.05**(±0.16)	3.97(±0.22)	3.77(±0.30)	**3.89**(±0.26)	3.75(±0.32)	3.74(±0.26)	**3.97**(±0.21)	3.86(±0.27)
Quality of Clip	2.95(±0.86)	3.24(±0.77)	3.86(±0.68)	**2.97**(±0.94)	3.19(±0.86)	3.09(±1.0)	**2.96**(±0.89)	3.12(±0.80)	3.54(±0.84)
Total Realism Rating	3.16(±0.75)	3.5(±0.65)	3.71(±0.66)	3.38(±(0.63)	3.45(±0.77)	3.39(±0.83)	3.09(±0.79)	3.18(±0.76)	3.21(±0.78)

Figure 10: Figure showing the table of results for the three different measurements of realism of the scene, as well as the general average for the different measures of realism, as well the the total realism rating for each frame rate

Looking at the table it is possible to see that 24fps generally had a lower mean average for the measures of realism between groups, whilst 60fps generally had the highest averages for the measures of realism between groups. Of all the means, 24fps had the lowest average under the motion blur perceived cinematographic realism of the clip measure with 2.83(±1.05), showing a disagreement with the statement that the scene was cinematographically realistic. 48fps had the highest measure under the motion blur realism rating, with 4.05(±0.16). Within the groups, 60fps had the highest total realism rating with motion blur, where the three previous statements are taken into account, even though 48fps had the highest overall average in one of the realism measures. In the group without motion blur 48fps had the highest realism rating, with the difference between the averages of the clips being smaller than with motion blur. In general there was not a considerable difference in the realism ratings of 48fps and 60fps. The bar chart in figure 11, shows a visual representation of the means under the different conditions, together with the general averages.

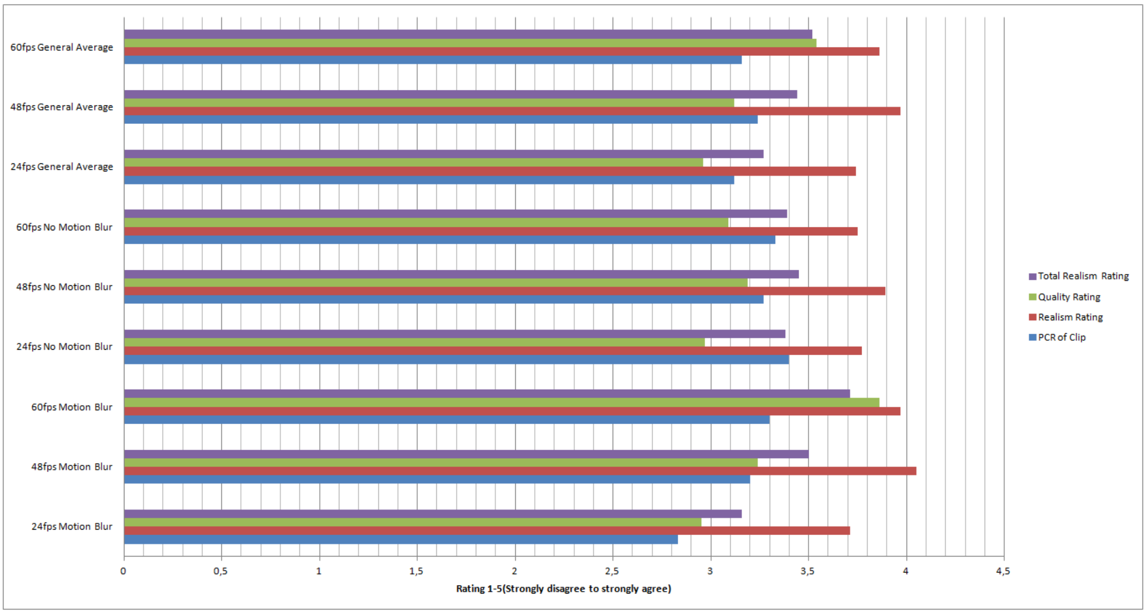

Figure 11: A bar chart showing the mean averages for the different measures of Realism.

The bar chart graphically shows, that generally the realism rating provided the highest ratings amongst the different situations. The PCR of the clips was rated the lowest of the realism measures when the clips contained motion blur, while it was rated higher than quality when there was no motion blur.

To find if there is any variance in the data, an ANOVA, with a 5% significance, was done on the different measures of realism results. The ANOVA tests found that there was no significant variation in the data amongst any of the realism measures represented in figure 10. The results of the ANOVA all presented p values that were greater than $p \leq 0.05$, meaning that the null hypothesis cannot be rejected. The realism measure that was closest to $p < 0.05$ was the interrelation between the samples with and without motion blur and the frame rates, for the PCR of the clips, the ANOVA results being $F(3.05) = 2.11$, $p = 0.12$. A student's t-test was run on the different variables for the PCR of the clips, finding that there was a significant difference ($p < 0.05$) between 24fps and 60fps with motion blur, as well as 24fps with motion blur and without it. A t-test was also run on the realism rating and the generalist realism rating samples, as the ANOVA test showed $p = 0.14$ for both of them, but the t-test did not reveal any significant differences.

6.1 Video Observations

To support the questionnaire data, the tests were both filmed and observed by the researcher. Out of the 41 tests that were performed, 37 were recorded, four failed due to technical errors. Of the 37 recorded and observed tests, 20 out of a possible 22 single test participant were recorded and 17 out of a possible 19 tests were recorded.

The video recordings showed that in 30 of the observed tests there was no change in behaviour of the participants, while in seven of them the behaviour changed both in positive and negative ways. In three of them the test participants were distracted by external factors such as sound or a person, in two the test persons got bored and in the two the test persons started to make car sounds. In the 17 observed tests, there was only one test where there was a clear distinction of one participant taking charge. In the remaining 16 tests, the participants spoke equally voicing their own opinions on the clips.

In all but two of the observed recorded tests the participants were seated upright, not slouching, and attentive. In one of the tests the participant was slouched and looked bored and in another the test participant chose to stand up. In eight of the tests there were technical issues, mostly related to changing between the animation clip and the online questionnaire, or the wrong clip being shown. The test participants had been told that they could talk during the test, though preferably not while answering the questionnaire. Nine participants did not say anything under the full duration of the test, 14 asked for help, mostly related to issues with the questionnaire statements. 14 participants talked about the clips at some point during the test, nine while watching the clip and five while answering the questionnaire.

The most common occurrences during the test were the participants asking for confirmation as to what they were doing, and to answer questions linked with the statements. Many where in doubt about *The Hobbit: An Unexpected Journey* in 48fps, not knowing whether it was the standard viewing frame rate. Some test participants were hesitant about the test, due to the lack of information about what they were testing for at the beginning, confirming, after being told everything, if they really did not need to know anything else. Due to the abrupt, unclear ending, the test participants had to be informed when the first clip was finished. This was because most did not realise it, and would sit waiting for more to come.

7 Discussion

Having presented the results, I will now proceed to discuss them and relate them to the hypotheses that were stated in Section 4.2. I will also be discussing some of the biases and problems encountered during testing.

First off I will discuss my single success criteria, which was that at some point the viewer would perceive what they are watching as being cinematographically realistic. This can be determined by looking at the averages of the measures of realism presented in figure 10. The general average results for realism indicate that the testers neither agreed nor disagreed with the clip being realistic, though the results are above 3.0, so it can be said that the success criteria only just passes.

The testing took place over three days in different locations within Aalborg University Campus Sydhavn and at Sparta Atletik's club house in Østerbro. An attempt was made to maintain similar testing conditions for all participants, though due to the different locations there were bound to b differences. The main priorities for the test were that the test participants not be told what was being tested for, and for them not to be distracted by a busy environment. In all the test situations the test participants were facing a wall so as not to be distracted by anything behind the screen on which the animation was being played. Unfortunately, due to lack of available rooms, testing in a noise free environment became nearly impossible. This may have lead to the test participants being less concentrated on the films, though the video observations suggest that the majority were focused on the test at hand.

Initially the thought was to only test on one person at a time, but due to the lack of dialogue under the test and the time it took to test one person at a time, it was decided to test on two at a time. This lead to more discussions while watching the clips, and unfortunately also to discussions while answering the questionnaires. This might be a source of bias, because by discussing while answering the questionnaires, and sitting right next to each other, the test participants could easily influence each other. This could lead to test participants who might not have noticed any differences between the clips, becoming aware of them, and also having participants who are unsure relying on the answers of a more assertive participants. It was deemed that the benefits of the discussion, and the support of having someone else in a similar situation, outweighed the bias.

It was observed that eight out of the observed tests had technical issues and that many of the participants asked for help during the test.. The technical issues were mostly in the beginning due to the use of an online questionnaire where the user had to press alt + tab to go between the questionnaire and the film, which confused many participants. For some of the participants the media player bugged and played the same clip again, forcing the observer to intervene. These technical distractions break the test participants concentration and could cause them to forget aspects of what they had been watching. Many of the test participants needed the observer to better explain some of the questionnaire statements, which suggests that the statements were not clear enough. There was also a mistake on the questionnaire, which was only noticed after a considerable number of participants had been tested, and that was that the speed rating scale was reversed, with very fast being 1 and very slow being 10. This confused many test participants who noticed it and voiced their confusion out loud, leaving the question if those who did not say anything noticed the reversal and paid it heed, or if they did not notice and answered as would be logical. This mistake may have rendered all conclusions pertaining to the speed of the car irrelevant. In the actual animation there were some glitches with the camera movements at higher frame rates which was distracting and possibly the reason why some of the viewers stated that the camera movements were the difference between the clips.

In spite of these biases it is still possible to draw conclusions based on the results gathered. The test was conducted on 60 people, 20% of which were female and 80% male, between the ages of 18 and 29. Of these test participants, 75%, considered themselves film enthusiasts, and 58% stated that they had knowledge of computer graphics. This allows for a tentative generalisation of the result, and a prediction that they reflect mostly the male population, who are in their twenties, and are interested in films, without necessarily having any knowledge of computer graphics. The fact that only eight test participants did not notice any differences between the clips, suggests that there are visible differences between the frame rates. This is supported by the previous research, and by the responses of the test participants who watched *The Hobbit: An Unexpected Journey* in 48fps, and wrote what they thought about it (figure 7).

The test was divided into two groups where one group, with 30 participants tested with motion blur and the other group, also with 30 participants tested without motion blur. The order in which the videos were shown was random, which lead to some of the orders being shown more often than others, forcing the researcher to plan some of the orders so that they were all shown at least once. Had more test participants tried the different orders, it might have been possible to see if there was a correlation between the order, and how the participants answered. Due to some of the comments made by the participants, about not knowing what to compare the first clip with, it is clear to see that the order affects their rating. This is because they use the first clip as a base on which to rate the other clips.

The Hypotheses will now be discussed in terms of the results, starting with the first hypothesis *The higher the frame rate, the more realistic the images will be perceived as being, while at lower frame rates the images will be perceived as being less realistic* and the null hypothesis *There will be no difference in the perception of realism between the frame rates.* Information on the test participants perception of realism was gathered in three different ways that were looked at individually, as well as being gathered into one total realism rating measure. Looking only at the mean values within each group, with motion blur and without motion blur, the results show that the clips at 24fps were generally rated at a lower realism rate than the clips at higher frame rates. This would suggest that it is true that higher frame rates produce more realistic results, though the difference rating is not that big.

An ANOVA test was performed on the data, that showed that there were no significant differences within the data, and that the null hypothesis cannot be rejected. I decided to try and applying a t-test to the result, PCR realism interrelation, which had the lowest p-value($p = 0.12$). It was found that there is a significant difference between the 24fps, with and without motion blur, which is more relevant for looking at the differences between the groups. There was also a difference between clips shown at 24fps and 60fps with motion blur, suggesting that though the null hypothesis cannot be disregarded, there is a case where my first hypothesis holds true.

The next hypothesis stated that *With the inclusion of motion blur there will be less of a noticeable difference between the frame rates*, with the null hypothesis stating that *Motion blur will not change the perceived difference between the frame rates.* This was measured by looking at how the test participants rated the statements for each clip within the group with or without motion blur. The more similar the answers the less of a difference they would have noted between the clips. Looking at the means for the total realism rating, the smallest difference between the results is noted in the clips without motion blur, suggesting that motion blur increased, rather than decreased, the differences between the clips. This hypothesis is partially linked with the previous one, and as such it is also influenced by the ANOVA test that was performed, which suggests that there are no significant variations between the groups. In this case again the null hypothesis cannot be disregarded, but also looking the perception of realism between the clips, it is possible to see that the opposite of my hypothesis occurs, with the motion blur increasing the differences between the frame rates.

The third hypothesis *The higher the frame rate, the faster the car will be perceived to be going* with the null hypothesis *The frame rate will not alter the perception of the cars speed*, and the final hypothesis *The test containing motion blur will increase the perceived speed of the car*, with its null hypothesis *Motion blur will not affect the perception of the cars speed compared to the test without motion blur* are both affected by the mistake in the questionnaire. The results for speed can only be used as a possible indication, without any certainty, since it is not known how many misinterpreted the question. Looking at how frame rate affects the speed of the car, based on the results it would seem that the car was perceived as going the fastest at 48fps and the slowest at 60fps. This suggests that my hypothesis about the car going faster at higher frame rates was true for 48fps, but not for 60fps, which means that the hypothesis was proven wrong.

Looking at whether motion blur affects the speed of the car for the different frame rates, the mean results showed that the car was perceived to be going fastest at 24fps with motion blur, but for 48fps and 60fps it was perceived to be going the fastest without motion blur. Again this suggests that based on the means of my results that my second hypothesis was also proved wrong. An ANOVA was also performed on the speed data, but it did not yield any significant variables in the data suggesting that the null hypothesis cannot be disregarded,

8 Conclusion

Having analysed and discussed the results I will now attempt to conclude on my final problem statement. To conclude on my problem statement I will take into consideration my hypotheses and my success criteria, as well as any relevant points that were discovered during the test. My final problem statement as presented earlier in this report is:

"How is the viewers perceived cinematographic realism affected when watching an animated action sequence at different frame rates and does the lack or inclusion of motion blur affect this perception?"

Firstly I found that my success criteria was only just met, which suggests that the clip was not realistic enough to the viewers. For all my hypotheses I found that the null hypothesis could not be disregarded, suggesting that there is not enough variance in the data, This could mean that there is no relationship between motion blur, frame rate and the perception of realism or the perception of speed. Looking at my four hypothesis individually, the first hypothesis saw a small difference between the frame rates in favour of my hypothesis, there was also some variance in the t-test between 24fps and 60fps further supporting that there might be some truth to my hypothesis. The second hypothesis was shown to be the opposite of what I had thought, with motion blur increasing the differences. For the final two hypothesis I found that my results proved my hypotheses wrong, with neither frame rate nor motion blur increasing the perceived speed of the car.

To answer my problem statement based on my hypothesis I would have to conclude that the viewers perceived cinematographic realism is not significantly affected by watching an animated sequence at different frame rates, nor is it affected by the inclusion or exclusion of motion blur. The results may have proven different if more people had been tested and if the test had been fault free. The faults being the question pertaining to the perceived speed of the car and the camera glitches in the animation.

9 Future Developments

This section will discuss whether there are future prospects in the chosen test method for this research, and what could be altered to improve the results. Due to the errors encountered in the test, it would be interesting to see if the results change when the test is performed free from errors, with the questions tested properly before hand and with an animation that is glitch free.

These tests were performed on a relatively small screen, that was not Full HD, and one of the benefits of higher frame rates is the increase in detail, which should be more noticeable on a larger screen. Also using a screen or projector with a higher refresh rate, might improve the viewing experience, or it might prove that at higher frame rates there are no differences when the refresh rate is higher.

Due to the lack of time for testing, I decided to test two people at a time, this meant that they could discuss what they saw while they were watching the film, and influence each other. It would be interesting to test on a large number of individuals to get their personal experience rather than a shared experience. Also by testing on only one person eye tracking could be used to note where the viewers looks, and to see how the different frame rates or motion blur affect what the viewers look at. It would also be interesting to test with a control group, where there are no differences between the clips, and see if the test participants still find differences between the clips.

The area this report focused on is an area where technology has been the main limiter for many years. With the present public awareness of frame rates, due to Peter Jacksons *The Hobbit: An unexpected Journey*(2012), and the talks of going even higher, investigating exactly what effects it has on the audience is a relevant topic. This report focused on how three different frame rates affected the perceived cinematographic realism of what the audience were watching, further looking at how motion blur affected the perception. This research could be expanded to even higher frame rates and look at its effects on viewers, or it could be used to find the point where the user begins to notice a difference.

An alternative, possibly easier, way for a test person to understand and test the notion of realism with computer graphics, could be to add computer graphics to live action footage. By doing this the viewer judges how much the computer graphics object is a part of the scene, or how realistic it appears, when motion blur and frame rates are increased or decreased.

List of Figures

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Master Thesis Questionnaire

You will be watching 3 animation clips. After watching each clip once, you will fill out one page of the questionnaire before proceeding to the next animation. At the end of the questionnaire there are some general questions pertaining all three clips.
The test is being video recorded for observation data. While watching the animation you can make any verbal comments you want about what you are watching. All information gathered will be treated anonymously.
Watch the first animation clip once and answer the questions below.

CLIP1

I perceived the clip as being cinematographically realistic *
Perceived Cinematographic Realism = what you are watching appears realistic/believable within the cinematic context it is shown.

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

It was easy to guess the outcomes of the actions in the animation *

	1	2	3	4	5	
Strongly Disgree	●	●	●	●	●	Strongly Agree

The scene was too confusing *

	1	2	3	4	5	
Strongly Disgree	●	●	●	●	●	Strongly Agree

The camera movements supported the action *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The scene had sufficient detail *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

I did not understand the action *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The car was an integrated part of the scene *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The camera movements were distracting *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

How fast did you perceive the car as going? *

	1	2	3	4	5	6	7	8	9	10	
Very Fast	●	●	●	●	●	●	●	●	●	●	Very Slow

Rate the quality of the clip

	1	2	3	4	5	6	7	8	9	10	
Very Poor Quality	●	●	●	●	●	●	●	●	●	●	Very High Quality

CLIP 2

Watch the second clip once and answer the questions below

I perceived the clip as being cinematographically realistic *
Perceived Cinematographic Realism = what you are watching appears realistic/believable within the cinematic context it is shown.

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

It was easy to guess the outcomes of the actions in the animation *

	1	2	3	4	5	
Strongly Disgree	●	●	●	●	●	Strongly Agree

The scene was too confusing *

	1	2	3	4	5	
Strongly Disgree	●	●	●	●	●	Strongly Agree

The camera movements supported the action *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The scene had sufficient detail *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

I did not understand the action *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The car was an integrated part of the scene *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The camera movements were distracting *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

How fast did you perceive the car as going? *

	1	2	3	4	5	6	7	8	9	10	
Very Fast	●	●	●	●	●	●	●	●	●	●	Very Slow

Rate the quality of the clip

	1	2	3	4	5	6	7	8	9	10	
Very Poor Quality	●	●	●	●	●	●	●	●	●	●	Very High Quality

CLIP 3

Watch the thrid and final clip and answer the rest of the questionnaire

I perceived the clip as being cinematographically realistic *
Perceived Cinematographic Realism = what you are watching appears realistic/believable within the cinematic context it is shown.

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

It was easy to guess the outcomes of the actions in the animation *

	1	2	3	4	5	
Strongly Disgree	●	●	●	●	●	Strongly Agree

The scene was too confusing *

	1	2	3	4	5	
Strongly Disgree	●	●	●	●	●	Strongly Agree

The camera movements supported the action *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The scene had sufficient detail *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

I did not understand the action *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The car was an integrated part of the scene *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

The camera movements were distracting *

	1	2	3	4	5	
Strongly Disagree	●	●	●	●	●	Strongly Agree

How fast did you perceive the car as going? *

	1	2	3	4	5	6	7	8	9	10	
Very Fast	●	●	●	●	●	●	●	●	●	●	Very Slow

Rate the quality of the clip

	1	2	3	4	5	6	7	8	9	10	
Very Poor Quality	●	●	●	●	●	●	●	●	●	●	Very High Quality

FINAL QUESTIONS

Did you notice any difference between the clips? yes no

If yes, what did you notice?

Age: Gender: Male Female

Do you have a background in Computer graphics? yes no

Are you a movie enthusiast? yes no

Did you watch The Hobbit: An Unexpected Journey in 48fps? yes no

If yes, what are your thoughts on the higher frame rate?

Any Further comments?