Cinematic High Frame Rates

The future of film, or aesthetic dead end?

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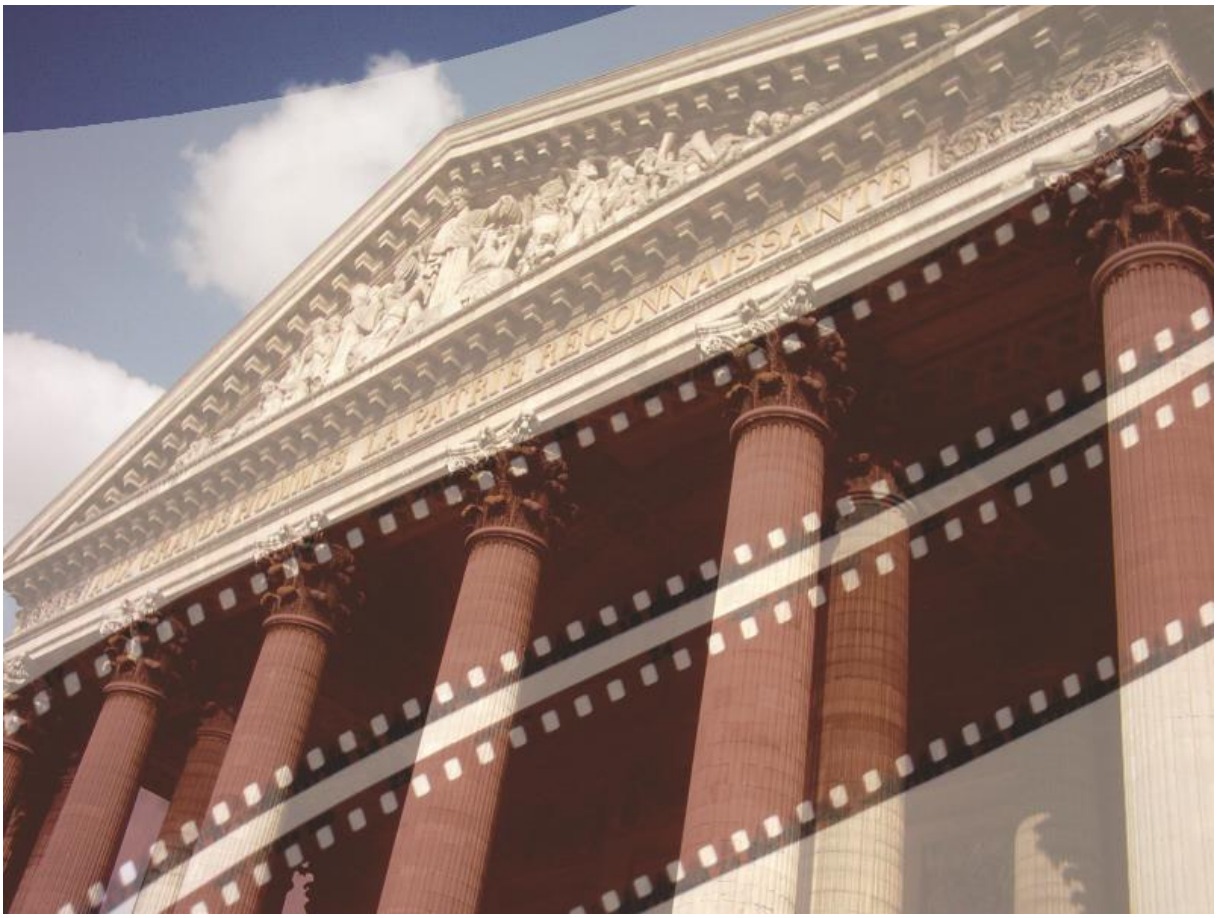

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Summary

HFR (High Frame Rate) technology for filmmaking has recently seen attempts at introduction into mainstream cinema. Despite showing considerable promise for benefits to the film experience, the technology has encountered problems with unfavorable audience receptions, linked to the particular aesthetic that a higher frame rate confers on the motion picture. This thesis explores the characteristics of these obstacles and the factors behind them, as well as the benefits that HFR also can bring onto the film experience. The results of this investigation indicate a significant steepness of the problems that HFR has encountered with its aesthetic reception, with possible contributions from factors that have currently not garnered much attention in the discussion surrounding the technology. Simultaneously, there are indications that higher frame rates' unique benefit for 3D viewing comfort tend to be slightly overstated, moderating the impetus for its adoption.

Sammendrag

Det har nylig blitt gjort forsøk på å introdusere såkalt HFR-teknologi (High Frame Rate) i kinofilm. På tross av å inneha et betydelig potensiale for forbedringer av filmopplevelsen, har teknologien møtt problemer med negativ publikumsrespons, i sammenheng med hvordan høyere bildefrekvenser endrer filmbildets estetikk. Denne oppgaven utforsker karakteristikker ved disse problemene og mulige, underliggende faktorer, i tillegg til fordelene som HFR også kan ha for filmopplevelsen. Resultatene fra oppgavens undersøkelser antyder at problemene med HFR-films estetiske mottakelse kan være svært substansielle, med mulige bidrag fra faktorer som foreløpig ikke har mottatt mye oppmerksomhet i den offentlige diskusjonen rundt teknologien. Samtidig er det indikasjoner på at teknologiens unike rolle i å forbedre visuell komfort og behag for 3D-film tenderer til å være noe overvurdert. Dette spiller inn i en reduksjon av det forespeilte behovet for teknologiens framtidige benyttelse.

Foreword

Many thanks to my counsellor over the past 17 months (spring 2017 - spring 2018), Prof. Liv Hausken. She has provided exactly the assistance I needed — not least with tempering my occasionally overflowing verbiage, stemming from an enthusiasm for the topics explored herein.

Also many thanks to my parents, for concern and support, and my younger brother Håvard, for some last-minute proofreading.

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Introduction

This master's thesis will conduct an in-depth investigation into a technological innovation in cinema known as "HFR", or "High Frame Rate". In its essence, HFR is the increase of one very fundamental parameter of film technology: the amount of unique still images, per second, that are captured by the camera — or rendered by a computer, in contemporary digital practices. We may here define HFR as any frame rate significantly exceeding the traditional 24 fps (frames-per-second) for cinema, standardized with the advent of sound film in the 1920s (Holman, 2013, p. 29). If nothing else is specified, HFR should be taken to mean a *doubling* of the standard frame rate (48 fps), or higher.

Commercial attempts at frame rates going above the traditional 24 fps, since its standardization, have a fairly long, if timid history: Two films were released in a short-lived 30 fps variant of the 70 mm "Todd AO" film process: The musical film *Oklahoma!* (1955) (Desowitz, 2014), and the comedy *Around the World in 80 Days* (1956) (Coate, 2016). In the 1970s and 1980s, filmmaker and special effects pioneer Douglas Trumbull sought to introduce the public to his 60 fps 70 mm format known as "Showscan" (Freymuth, p. 131, 2014). Showscan did not achieve a commercial breakthrough. HFR, together with 3D, was set for a resurgence with the 48 fps-presentation of *The Hobbit: An Unexpected Journey* (2012) — the first part of Peter Jackson's Tolkien-based fantasy film trilogy. Although the 48 fps-version of the film was only available in a limited amount of theaters, the format was given considerable momentum by one of the biggest blockbuster movie events in recent years. The increased frame rate was given the marketing label "HFR 3D" (Liszewski, 2012): Among its selling points were a significant increase in image quality, an enhanced sense of realism and/or immersion, and the ability to make 3D more comfortable and pleasurable to watch (Turnock, 2013, pp. 30-31).

The "HFR 3D" version of *The Hobbit* was met with a very mixed response, however, and some significant backlash. Although realism was a touted strength of the format, HFR apparently ran the risk of seeming "too real", in some sense: actors and film sets were prone to being perceived *as* actors and film sets, rather than the fictional characters and milieus that the film intended to invoke (Laforet, 2012). This stands in contrast to the otherworldliness and suspension of disbelief that cinema proved well capable of invoking with Peter Jackson's precursory fantasy film trilogy, *The Lord of The Rings* (2001-2003). Complaints were also abound that *The Hobbit* didn't look like "film", and instead garnered associations with

television, prominently. A frequent invocation was the *soap opera* — a "soap opera effect" — to describe an overall aesthetic effect that came from the increase in frame rate (Frazer, 2012).

These peculiar problems appear to have contributed significantly to cooling the interest in a widespread adoption of higher frame rates for cinema, even if there appears to be much promise inherent in the technology. This thesis seeks to investigate a full picture of how the viewing experience of HFR film relates to the current state of resistance to its adoption — taking into account important *benefits* to said experience, and the drive this may create for the technology's mainstream adoption, as well as the potential problems and *obstacles* it has encountered. This has led to the formulation, of an overarching research question for this thesis, which reads as follows:

> **Main research question:**
>
> **What effects do HFR formats have on viewers' experience of cinema, and why does it have these effects? What conditions do these effects pose for the possibility of a future breakthrough of HFR cinema, after a difficult beginning?**

This question prompts an investigation into different main aspects of how HFR contributes a change to the traditional film experience, to be delineated below — as well as an investigation into the traditional film experience itself, as this reflects back on frame rates higher than 24 fps. Whereas some aspects of HFR cinema and its particular visual experience have previously (and recently) received some short-form scholarly treatment, there has — to the extent of my knowledge — been produced little in the way of longer, comprehensive treatments of several important subtopics of HFR simultaneously. (Such previous works will be outlined in the introductions to the various thesis chapters, to which they thematically adhere).

Chapters

The three chapters, into which the answering of the research question has been structured, have the following scopes:

Chapter one will look at HFR and its impact on *viewing comfort* in the film experience — a purported ability of HFR to make film more pleasant to watch, with regard to factors such as eyestrain. This particularly (although not exclusively) pertains to 3D, which faces greater challenges with viewing comfort than 2D film. Viewing comfort is one of the main,

advertised benefits with HFR — and currently, it appears to stand far apart as its most concrete and consequential one. More diffuse claims for advantages — such as an enhanced "immersion" in the film experience — have been significantly undercut by an entirely contrary effect, of the kind of problem with "disillusionment" indicated above. The potential for HFR to remedy purported disturbances to a comfortable (and thereby pleasurable) film experience may contribute heavily to a felt necessity of its adoption, however, especially with the film industry's considerable investment in 3D technology (Turnock, 2013, p. 31). It is thus a particularly salient factor to consider in the investigation of benefits to the HFR film experience, and the conditions for its future adoption.

Chapter two will investigate the apparent main body of the controversy pertaining to HFR: that of a so-called "soap opera" or "televisual" effect, and a related, unfavorably enhanced realism — both of which relate to an apparent loss of the "cinematic", by way of defeating the visual conventions that audiences have come to expect from 24 fps film. I will here endeavor to shed light on HFR film's relationship with the various genres and types of media that it is purported to resemble, typically at the expense of cinema. Clarifying the nature of these issues should be central to clarifying the steepness of the apparent problems that HFR film is currently faced with.

Chapter three presents an exploration into possible factors lying *beyond* those most widely discussed obstacles of HFR, treated in chapter two — factors which may have some contribution to make toward a full account, of the apparent potency with which HFR engenders the types of aesthetic responses that it is reported to do. Central here is a consideration of the traditional 24 fps format for its *own* kind of (possible) potency, converse to that of HFR, in conferring an aesthetic that is seen as appropriate to cinema. This appropriateness may be entirely attributed to viewers' conditioning — to a certain, accustomed "look" for cinema — but chapter three will offer some resistance to this, and ask whether there could be a deeper view to be had onto 24 fps.

Theory and methods

The main research question has prompted quite different areas of interest, as outlined with the chapter descriptions above. I have thereby found it necessary to make choices, for theoretic and methodical approaches, on a chapter-by-chapter basis — with a resulting, marked difference in perspective between chapters.

This is particularly clear for chapter one, where the issue of viewing comfort prompts what is essentially a natural-scientific field of pre-existing knowledge. Potential viewing discomfort arises from particular manifestations of optic phenomena impressing themselves on the human eyes, in ways that vision science can describe and account for. For cases of physical eyestrain and eye fatigue, resulting from these phenomena, ophthalmology and related fields may give an adjoining, objective description of underlying biological mechanisms for these problems. In chapter one, then, I consult various expert sources of knowledge — from technical-scientific papers and reviews, to statements by professional practitioners in the field of 3D — to investigate what proves to be a complex and multi-faceted topic of viewing discomfort and contemporary cinema. Certain works of research and other sources signal a preeminent importance here, with regard to particular subtopics — these will be indicated in the introduction to the chapter. This approach, and the literature involved, is expected to provide a certain reading challenge, for a non-technically schooled investigator such as myself. I am confident that this should not prove more than an engaging and surmountable challenge, however — and the result of the investigation, contained in chapter one, will be communicated with care for the non-specialized reader.

Chapter two will leave a technical-scientific approach in favor of a humanities-driven one. The formal analysis of HFR film and related audiovisual expressions will be foregrounded in this chapter, in order to investigate how HFR film's formal qualities can contribute to eliciting the effects that it reportedly has on viewers. A theoretical perspective that will take precedence, in conjunction with this analysis, is a set of ideas provided by J.G. Butler (1986) by way of John Ellis (1982), among others. The essential claim of these ideas is that certain configurations of moving images may give a sense of being more "live" than others, by virtue of their formal characteristics — unfolding as if in a more "immediate presence" to the viewer. This perspective appears to have a considerable affinity with reports of HFR film being apprehended as "live", or "televisual", and thus warrants a central role for the investigations of chapter two.

Chapter three will in large parts be formed by a perspective derived from *cognitive science*. As indicated with the outline above, it is centrally concerned with the possible uncovering of factors which can deepen or refine the understanding of frame rate and its effect on the experience of film. Cognitive science, particularly the science of the brain, appears especially promising in providing concrete and non-trivial results to the project of investigating and developing possibilities for such factors. Particular interest is tied to the scientific evidence

for clearly differentiated pathways for motion processing in the brain: *long range* and *short range* motion processing, as described by psychologist Oliver J. Braddick (1980), among others. Various objects for investigation and formal analysis will be activated in conjunction with the cognitive perspective — some highly typical examples of 24 fps film, prominently. These stand in for the general, common experience of film spectatorship, which we are most centrally interested in here. There is also an incursion from a quantitative approach — where actual distances of movement, from one frame of film to the next, are measured. This is in correspondence with the quantitative dispositions of relevant, theoretical underpinnings provided by neuroscience, such as those pertaining to the brain's systems for motion processing.

Chapter three will also, for a smaller treatment, discuss the issue of frame rate in light of a classical *formalist* perspective on film theory — particularly that found with film theorist Rudolf Arnheim. There is some overlap with a cognitive perspective here, in the Gestalt psychological underpinnings of Arnheim's thought on film and art (although the specifics of Gestalt theory will not be utilized here). Similarly to the other approaches of chapter three, this perspective holds particular promise in speaking efficiently to the open question posed for the chapter. This is not least because HFR can be seen to occupy a similar position as other, technological innovations in cinema's past, which fell under criticism from a formalist perspective, for an unwarranted pursuit of greater "realism".

Broader interest

The topic of HFR technology for cinema draws particular interest for its bearing on the future of the theatrical cinema experience — and thereby also the future of the motion picture as a communal, large-scale social event. Seeking to make the theatrical film experience more unique and attractive to audiences, in an age of ubiquitous high resolution screens and home entertainment, the industry appeared to inadvertently court the opposite: to make cinema *less* "special", perhaps more like a range of media experiences found in television. Meanwhile, the transformative effect that HFR has on cinema also spells difference and distinctness from home entertainment: Nothing quite like *The Hobbit* in HFR is available currently, to watch at home — and the format may have been poised to give 3D cinema new life. Why did HFR, for all its potential, seemingly grind to a halt after the mixed reception of only one large-scale attempt*?* Why is there hardly any current signs of further attempts at utilizing this potent

technology — with the newest array of fantasy and "superhero" action films, for instance — so as to give mainstream cinema an edge over its fierce competition?

The answers to such questions may additionally speak to how film *art*, and the finer sensibilities and subtleties of that art, could in surprising ways resist a rapid drive for quantifiable (and thus sellable) technological progress — more pixels, more frames, etc. — even within the rigidly profit-driven confines of mainstream Hollywood. The nature of such a resistance may reflect on the current, cultural position of film in itself, and may be brought into a better light through an engagement with the finer points of how HFR transforms the old, "gold-standard" 24 fps film.

Notes on referencing style/technique:

Harvard style, drawn from the University of Leeds Harvard referencing style, with some slight typographical changes.
(https://library.leeds.ac.uk/info/1402/referencing/50/leeds_harvard_introduction)

Specific timestamps for videos may adjoin in-text citations, similar to page numbers. The formula is always: hours:minutes:seconds.

[Bracketed] segments in quotes are always my own comments, if not explicitly stated otherwise.

CHAPTER ONE: HFR and viewing comfort

Introduction

The first chapter of this thesis will begin with a look at HFR technology's relevance for *viewing comfort* (or visual comfort) in the film experience. Amid the backlash over the "soap opera effect", and related issues, one promise for HFR might have held up more easily: the 3D film experience was possibly *easier to watch*, more comfortable to the eyes, compared to 3D at a traditional frame rate. 3D generally has a problematic relationship with visual comfort, owing to a multitude of factors (Lambooij et al. 2009, p. 1). HFR has the ability to reduce or eliminate particular motion-related "artifacts" (Watson 2013, p. 18), associated with lower frame rates, and these artifacts are held to pose problems to visual comfort — especially in 3D. To begin to gain a slight impression of what these motion artifacts are, and the significance they may have for viewing comfort, consider the following statement made by director Peter Jackson — on his Facebook page, prior to the release of the first *Hobbit*-film in 2012:

> It [HFR] makes the 3D experience much more gentle and hugely reduces eyestrain. Much of what makes 3D viewing uncomfortable for some people is the fact that each eye is processing a lot of strobing, blur and flicker. This all but disappears in HFR 3D.
>
> (Jackson, 2012)

The particular natures of these artifacts (here referred to by Jackson as "strobing, blur and flicker") will be given a thorough exposition below. As a general starting point for the term "artifact", which will run through much of this chapter, the following dictionary definition captures the intended meaning reasonably well: "a defect in an image (such as a digital photograph) that appears as a result of the technology and methods used to create and process the image" (Merriam-Webster, 2018). (There is no particular emphasis on "defect" and the values implied in that word, however).

While the reduction of motion artifacts appears to be HFR's primary implication for viewing comfort, it is not necessarily the exclusive one. Other consequences of the technology may also be important, and will be considered here — although the reduction of artifacts appears to be highly foregrounded, as seen with Jackson's statement. Therefore, this is taken as a base for the topic of HFR and viewing comfort.

The issues signaled here are ones that on one hand are matters of aesthetics: motion artifacts, or other distortions of the normal (and comfortable) human view onto the real world, may be deemed an unattractive and visually displeasing incursion upon the film experience. These may therefore be "uncomfortable" to watch, in that particular sense — and are included in the scope of this chapter. They may also constitute further impediments and complications for the human visual system, however, as it vies for the quality of sensory information that would be available in a real-world viewing situation. Therein enters possible issues of eyestrain and *physical* discomfort in watching film, going beyond a mere aesthetic displeasure. Through this potential to displease, and also to actively disturb movie-watching as a leisurely, comfortable activity, these issues are regarded to inhabit a distinct and important position in the overall subject of HFR cinema. Therefore, they are preliminarily singled out for consideration, before proceeding to other, central issues in subsequent chapters.

Chapter questions

- How do issues of viewing comfort, in current 24 fps film, differ between 2D and 3D?

- What are the added benefits to viewing comfort when employing HFR for 3D, compared to 2D? How significant is any difference here?

- What impact do such added benefits have on an overall perceived problem of visual discomfort, specific to 3D?

- For comfort issues that HFR can help to remedy, whether 2D or 3D: to what degree does HFR currently appear to be the *only* solution to these, and how does this differ between various problems?

- For comfort issues which HFR *cannot* help solve, how significant could the solving of these be for the overall experience?

Despite the prevalence of the idea expressed by Jackson in the above quote, the exact *what* and *why* of how 24 fps is particularly problematic for 3D (even troublesome to the point of eyestrain) can be somewhat unclear. Explanations tend to be fairly abbreviated, like the one above, and generally do not do not delve into more exact, technical matters. In order to

answer the above questions, the first and second most directly, I will attempt to clarify and/or ascertain the problems with 3D and 24 fps through more fleshed-out sources. This investigation into 3D should provide a baseline from which to also explore HFR's significance for 2D. Despite the focus on 3D, inherited from the industry's focus on HFR film in 3D, there is considerable interest in what benefit HFR might bring to 2D filmmaking as well.

Furthermore, in order to interrogate the impact that HFR is poised to have on the broad, general problem of visual discomfort with 3D — as the third question indicates — the discussion has to be opened onto *all* facets of this issue. This will move the discussion beyond motion artifacts and onto a wide array of topics, in which HFR *may* play a part (which will always be considered), but also where it is likely to be irrelevant. This becomes important to establish, in and of itself — for instance, if there exists a significant source of viewing discomfort in 3D, for which neither HFR nor other technologies (or techniques) seem to provide a remedy.

The bottom two questions stem from an interest in *alternatives* to HFR. HFR is only one avenue out of many, from which possible benefits to the viewing comfort of the film experience can be derived. The willingness to tackle the aesthetic pitfalls that HFR has proven to reveal, is likely to depend on the *magnitude* of benefits to viewing comfort, and also the *exclusivity* of these: there may be alternative means to attain similar positive effects, or potential for different positive effects entirely — both implicated in an overall reduction of significance of HFR, as an aspect of future filmmaking.

Structure and previous work

The investigation into these questions will take the following structure: I will begin with some necessary description of motion artifacts, clarification of terminology pertaining to them, and a brief consideration of how these visual phenomena have traditionally been dealt with in film. After this, I will provide a brief interlude where I consider motion artifacts' relation to film scholarship. Traditional film theory may appear to be somewhat sidelined by the notion of visual comfort employed in this chapter, which may be more in line with the concerns of the film industry (or related industries). This warrants some explicit acknowledgement. Following this, for the main section of the chapter, I will look in-depth, *point by point*, at the various domains of purported *deficiencies* with the 3D (24 fps) experience in today's cinema. I will consider these in light of the range of questions outlined above: how significant these

issues appear to individually be, what role HFR may play in their modification and/or improvement, and so on. As these issues intersect with relevant sources of information, these will be brought up for analysis. Through establishing a clearer view on 3D, there should be an emerging, complementary picture of how the standard 2D 24 fps format is situated.

Sources used throughout this chapter are typically, although not exclusively, of a technical-scientific nature — research (and research reviews) from the fields of vision science and display technology, particularly. An experimental study of the visibility of motion artifacts, by David M. Hoffman et al. (2011), should be emphasized for having been an important contributor to the investigation — as well as a related study (involving some of the same researchers) by Paul V. Johnson et al. (2014a, 2014b), also on the visibility of motion artifacts. As far as I have been able to tell, these provide a fairly unique insight into some of the issues that are relevant to this chapter. These studies also utilize a useful theoretical model for motion artifact visibility, provided by vision scientist Andrew B. Watson: the "window of visibility" (Watson, 2013). This model will at times be activated here, in general and in relation to those studies specifically.

Yet other important aspects, of the multi-faceted topic at hand, are not spoken to by these sources. Other contributors will have to be introduced as needed. It may however be mentioned, in advance, that I have been fortunate enough to gain input from e-mail correspondences with some professionals working in the field of stereography and 3D cinema. Directly cited here are Matt Cowan, who was Chief Scientific Engineer during the development of the widely used "RealD 3D" system for 3D cinema (Cowan, 2018b), and Ray Hannisian, freelance stereographer and 3D consultant (Hannisian, 2018).

As far as I have been able to tell, there appears to be a need for a holistic treatment of the issue of HFR and visual comfort: a treatment which integrates various sources of technical information into an overview of HFR's overall, practical significance for visual comfort, as this pertains to cinema in particular. The intention of this chapter is to contribute to such an integration — and thereby provide one important piece to the overarching questions of this thesis.

Motion artifacts: terminology, description, discussion

Before going further into the questions for this chapter, and also in order to answer them, we will have to consider a set of terms for motion artifacts — and the phenomena they correspond to — that will be fundamental to the investigation to follow.

Judder and motion blur

The term "judder" may be found in colloquial discussions surrounding motion artifacts, as well as in scholarly literature. While particular instances of the latter may clearly define what "judder" refers to (for the purposes of a particular work), it seems that there in both domains is a propensity to assigning various exact meanings to the term. In one explorative study of judder, as it is defined in that study, Scott Daly et al. (2015, p. 62) state that they use the term as an *umbrella term* for a range of different visual manifestations of motion artifacts. Hoffman et al. (2011), which will be consulted extensively in this chapter, use the term differently and more specifically. I will, for the purposes (and conveniences) of this thesis, endeavor to unequivocally ascribe “judder” to one particular phenomenon, as it is typically experienced during movie watching. This will follow immediately below. Where sources used deviate from this usage, attention will be called to this as needed.

Camera movements, in traditional 24 fps film, are especially associated with what will here be designated as “judder”. Situations in which objects in the picture move in a regular (steady) manner across the screen, prompting our eyes to *track* them, are very prone to cause a characteristic "vibrating"-effect. This could for instance be a camera panning or tracking horizontally across a picket fence, or vertically scrolling lines of text during film credits. Looking at a specific slat of said picket fence, its edges may seem to "shake" or "vibrate" — in more severe cases producing what can be perceived as a kind of unresolved double-image. As pointed out by James Larimer et al. (2003, p. 1042), there may also be an impression of the edges of these objects "flickering" — i.e. quickly "strobing", in an on-and-off manner.

Recounting his impression of the opening to *Casablanca* (1942), in a restored and remastered Blu-ray-version, one home theater enthusiast describes judder in the following way — which serves to capture just how it may become highly problematic, under very normal film-viewing circumstances:

> At two minutes and 3 seconds into the film, the camera holds the skyline for a moment, then pans slowly down to street level. You recoil in horror as the picture comes completely unhinged. It stutters and shakes like a delirious madman. The buildings are seemingly in the throes of a bizarre earthquake. It hurts to watch it.
>
> (Powell, 2008)

To be noted, the judder does not stem from still images exhibiting any of this effect — they are not actually *on* the film, in any capacity:

Fig. 1.1: Downward "tilt" from opening of Michael Curtiz' *Casablanca* (1942)

The camera is tilting, moving down, at a relatively quick pace, in the above shot. Compare this to the idea of scrolling film credits, above, or imagine that the image was rotated 90 degrees, so that a horizontal movement would be taking place — analogous to a camera tracking across a picket fence. There is, to be noted, a slight *motion blur* here, which is actually seen in the screenshot — just slightly softening a sharp view of the buildings. This is *not* the "judder" effect. This blur stems from the exposure time of the camera, and *does* translate onto the still image. There is no trace of the distinct shaking or “double-image” that will here be called "judder", however. Figure 1.2 provides a clear example of the motion blur that is faintly seen in figure 1.1 — here being created by rapid hand-movement, captured in a still image:

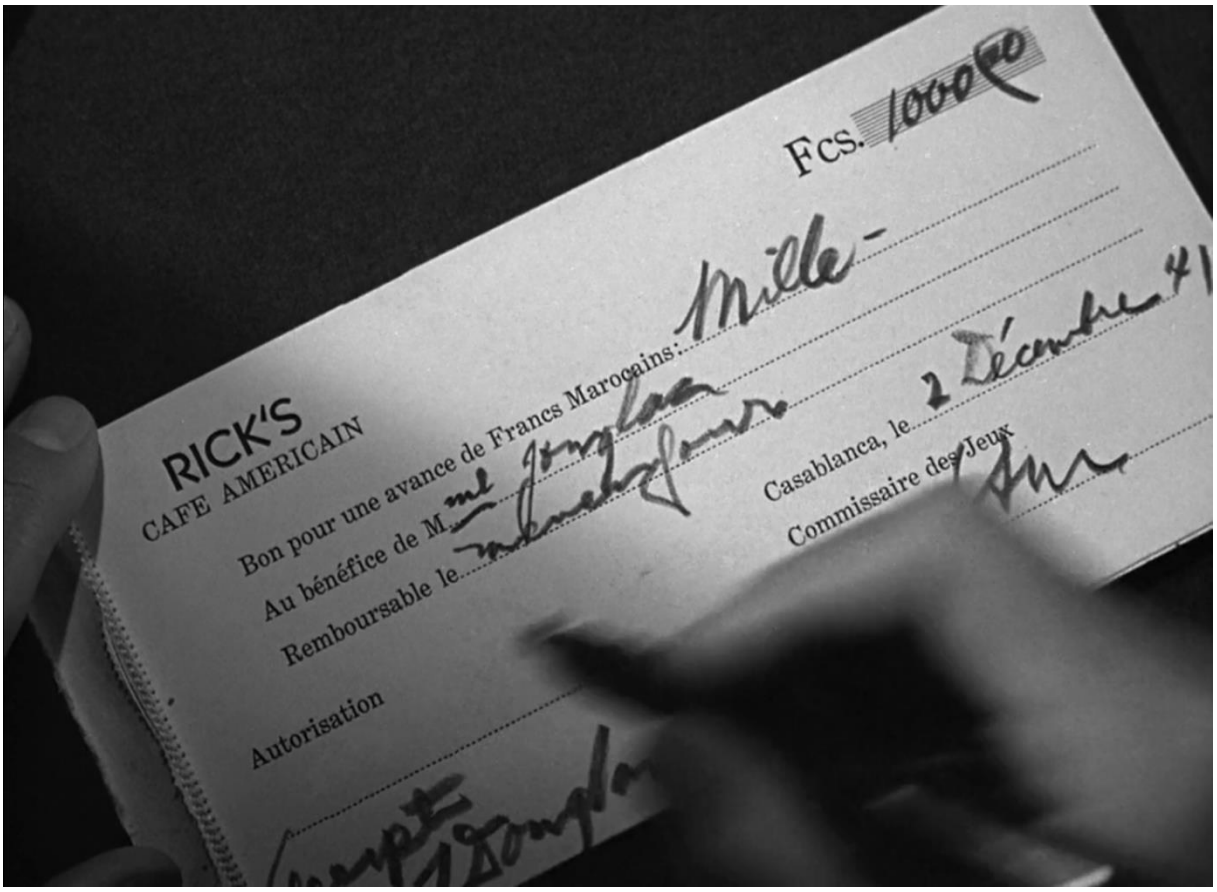

Figure 1.2: Motion blur, from *Casablanca* (1942)

While often appearing in conjunction, we can thus reasonably distinguish two different phenomena here. “Motion-*blur*” or “-*smear*” will generally be used in this thesis, for the phenomenon seen very clearly in figure 1.2 — which is the result of a certain camera exposure time, in conjunction with a moving camera or a moving object. “Judder” will be used for the “shaking”-effect that is described with the opening of *Casablanca* — which only exists *in the eyes* (on the retinas), during the course of actually seeing a film move.

In contrast, Hoffman et al. (2011, p. 8) uses “motion blur” to describe the in-eye process that gives rise to the "shaking" or "juddering" effect. Granted, this process does involve a type of “blurring” of a given stimulus on the retina — an explanation of this will follow below. There is not an argument to be had with the allocation of terms here, it is rather only a practical choice to delineate terms in the manner described above, for this thesis. "Motion blur" is already used to refer to what is seen in figure 1.2, which is a phenomenon that is also very important to this chapter — while the apparent "shaking" described with *Casablanca* plots very appropriately onto the denotative meaning(s) of the word "judder".

Motion blur on film is essentially the same, well-known effect that can be created and observed with slow exposure times in still photography. A closer explanation of judder should be warranted, however. (I am now using the term in the way that has been defined for this thesis). Judder stems from our eyes *tracking* — moving with some on-screen stimulus — but being unable to clearly resolve a singular location for it (at the center of the retina.) "Observers typically track a moving stimulus with smooth-pursuit eye movements that keep the stimulus on the fovea" (Hoffman et al., 2011, p. 8). Such smooth-pursuit movements interact with stimuli in a particular way when said stimuli are moving in *significantly wide, discrete steps* — such as with the movement of 24 fps film. Put another way, our natural eye movements — intended for tracking perfectly smooth-moving objects — are not a perfect match for the conditions posed by traditional cinema, where objects "skip" locations on the screen (and thereby also on the retinas) significantly. Concluding a highly technical explanation for this, Hoffman et al. (ibid.) state that "significant displacement can occur with high stimulus speeds and low frame rates thereby blurring the stimulus on the retina ("motion blur")." A higher speed increases the severity of the effect, due to the corresponding increase in displacement of an object, from one frame to another.

Judder, as a motion artifact, can also be conceived of in terms of a *signal processing* perspective. Viewing a film, the retina is seen as receiving a *sampled* version of a signal originating in the real world (i.e. 24 samples per second, for traditional film). A model known as the "window of visibility" has proven useful in determining when artifacts from such sampling — typically, *too low* a sampling rate to accurately represent the real world — actually intrude upon human vision. As stated by one of its originators, vision scientist Andrew B. Watson (2013, p. 18), the window of visibility is a "simplified representation of human visual sensitivity to spatial and temporal frequencies" — such frequencies constituting a spatial-temporal signal, like a moving film. Watson shows how, changing the variable of motion *speed* (the speed of an object travelling across the screen), signal frequencies associated with artifacts will intrude upon the window of visibility in different ways. These different entries may be onto *low* temporal, *high* spatial frequency areas of the window, or vice versa — which in turn correspond to different characteristics of artifacts experienced by the viewer. They may appear as "multiple images" (low temporal, high spatial frequency), or as a "flickering" (high temporal, low spatial frequency) (ibid.). For the experience of judder when tracking an object, this appears to correspond with my own observation and impression that moving scenery seems only to quiver (or "flicker") slightly with a very slow camera pan

— while it breaks apart into a more severe "alternation", between several "imprints" of the image, when the pan is faster.

A final, introductory note on motion blur, in light of Watson's model: motion blur is, for all intents and purposes in this thesis, to be considered a type of "motion artifact". It is a particular, perceivable product of the film recording process, inherent to the motion seen with traditional film — and thereby a phenomenon of interest that is to be regarded alongside judder. It is not an artifact stemming from insufficient sampling in time, however, and thus not a phenomenon that Watson's model covers as an intrusion upon its "window of visibility". To the contrary, longer exposure times (with resultant motion blur) works to limit signal frequencies that threaten to enter the window of visibility, thereby having "a powerful [reducing] influence over the intrusion of visual artifacts." (ibid., p. 20) To my knowledge, in the context of film, the term "motion artifact" is not rigorously defined — and thus not narrowed compared to the fairly broad dictionary definition cited above (page 17). For this thesis, at least, motion blur constitutes a "motion artifact".

Unsmooth motion

Judder is highly related to, but can also be distinguished from a more general impression of there being "gaps" in the motion of 24 fps film — rendering its overall motion "unsmooth". An example of this, that will be made use of at various points in this thesis, is the "staccato" sense of movement found in Steven Spielberg's *Saving Private Ryan* (1998). In key action scenes in the film, there is an increased sense of elements in the picture "jumping" in position. This is an effect that one would also see exacerbated with film or animation at frame rates lower than 24 fps, but *Saving Private Ryan* did not achieve this through decreasing the frame rate. This effect was produced by deliberate decreases in exposure time for each frame, for certain shots. Cameras were set to expose the individual still image for less than the standard 1/48th second — thus reducing motion blur (Thomas, 2013, p. 226). (Motion blur has an attenuating effect on the visibility of motion artifacts, as mentioned). What is seen with this unsmooth motion can perhaps be thought of as the more basic artifact of film's "insufficient" sampling of motion — one which *takes the form of judder* when the eyes are specifically engaged in the *tracking* of an object. Hoffman et al. (2011, p. 8) assign the term "judder" specifically to unsmooth motion, this general lack of smoothness. In this thesis, however, judder remains distinctly reserved for the particular "vibrating" phenomenon seen when tracking objects. A general, perceivable lack of smoothness of motion, as seen with *Saving*

Private Ryan, will be referred to in just those terms: "unsmooth motion", "lack of smoothness", etc. (Also, the term "staccato" may occasionally be used, as done above).

Mitigating factors

The visibility and severity of these motion artifacts, described above, may vary significantly depending on how a film is created and presented.

Contrast level, the relative differences in brightness between various on-screen elements, affects the visibility of sampling artifacts such as judder and unsmooth motion (Watson, 2013, p. 26). Consider the example of a horizontal pan across a (white) picket fence, used earlier. The fence slats will more visibly judder if the fence is illuminated in a nighttime-scene, compared to the same scenario in broad daylight, due to a stronger contrast between elements. Correspondingly, the camera tilt from *Casablanca* is likely to judder more if one turns up the contrast setting on a TV set — or introduces contrast through other means, such as viewing the TV in a darker room.

Also, the slight periods of darkness in between each flash of an image, caused by the mechanical shutter during traditional film projection (Case, 2013, p. 158), may help the eyes in mitigating the perception of judder. Modern LCD TVs, as well as digital cinema projectors (DLP projectors), are "sample-and-hold" in nature (Koebel, 2014) — meaning that for the 1/24th second slot allotted to the presentation of a single frame of a regular film, the frame is fully present for all (or the very most) of that time. This would afford no such mitigation. In a 2005 study of artificial "black data" (i.e. dark period) insertion in LCD displays, Sunkwang Hong et al. (2005, p. 11) assert that such methods can bring a marked improvement to the appearance of motion during eye-tracking. There seems to be a potential for lessening the impression of judder through such methods — methods that could perhaps also be subject to further development and improvement. This can, importantly, be done without modifying the traditional 24 fps frame rate. Also interesting, it may be noted, is the implication that judder may have slightly *worsened* with the general move from analog to digital projectors in today's market — with a loss of the dark interstices in traditional projection.

More generally, filmmakers may go to great lengths to avoid and divert attention from judder, during production. As treated above, higher speeds of a moving object increases the severity of the judder effect — prompting the need for carefulness with the speed at which a camera pans across a scene. The American Cinematographer Manual (ASC, 2013, p. 1115), published

by the American Cinematographer Society, includes charts and instructions for "best practices" for panning speeds, at various frame rates. There are also certain sleights-of-hand of filmmaking, such as having the viewer look on some element in the foreground — typically an actor — that moves with the speed of the pan. This would divert attention from the juddering background.

Assuming normal parameters for frame rate and exposure, restricting speed appears to be the only way to reduce *motion blur*. Motion blur, as we have considered, is inherently "there" on the still images of film — it is thus not prone to be reduced beyond the degree to which its actual recording is reduced, during production. It is also usually *desirable* to have with 24 fps, for its attenuation of unsmooth motion. While the creators of *Saving Private Ryan* deliberately used the effect of sparse motion blur for artistic purposes, viewing all films in the resulting "unsmooth" mode would likely pose a problem to viewing comfort.

Motion artifacts and film scholarship

Since the standardization and maturation of 35 mm at 24 fps, as the ubiquitous “canvas” of cinema, the motion artifacts described above may themselves have become part of a process of conditioning — naturalizing them and making them "transparent". David Bordwell’s take on this subject, voiced on his blog in 2012 (around the time when the *Hobbit*-trilogy was on the cusp of release), can perhaps be taken to portray a certain academic disinterest in a perspective on film motion as "deficient" — i.e. as ridden with "artifacts", which intrude upon viewer experience, and may possibly be in need of elimination:

> Moreover, Cameron prepared a demonstration that showed that in 3D, figure movement and camera movement strobe noticeably at the 24 fps rate. They look much smoother at 48fps. This is probably true, but I haven’t noticed problems of strobing in 35mm films by Mizoguchi, Jancsó, Welles, Renoir, and other camera-movement masters. Since they didn’t use our modern 3D, they didn’t encounter the artifacts that Cameron and his peers now brood over.
>
> (Bordwell, 2012)

This perspective could be a means of accounting for how the subject of motion artifacts appears to be dominated by work on technical aspects of (and possible remedies to) them — whereas there is less attention to judder as a sheer formal characteristic of the film experience,

for instance. It may be a techno-progressive "engineering-attitude" that fuels much of the interest in these matters, which misses the mark for a more humanities-driven approach. Scholars of film as art — or more broadly, as a multi-faceted yet powerfully holistic media experience — may understandably be less concerned with fine-grained technical limitations. Additionally, these are limitations that filmmakers/cinematographers take care to operate inside of, meaning that *they* could be quite concerned with motion artifacts — while the remaining traces of judder on-screen, as a result of their work, are relatively mild. Although we will investigate the particular technical implications of 3D below, there appears to be very little question that 24 fps itself brings with it some noticeable artifact-related troubles — also in 2D — contrary to Bordwell's suggestion, above. In one interview with video podcast Home Theater Geeks (2015, 0:03:50), Douglas Trumbull, who worked on the special effects for *2001: A Space Odyssey* (1968), recalls director Stanley Kubrick and himself having to deal with the noticeable juddering of bright white stars and spacecraft, as they moved against a dark background. Even with the characteristically clinical control that Kubrick brought to the final result, judder is an intrinsic part of 24 fps — and quite hard to completely avoid.

The current 3D cinema-experience

We will now, for the rest of this chapter, turn to an investigation of the state of the current 24 fps 3D cinema experience as it is enabled by contemporary movie theaters. The overarching task that is being set here is to single out the different issues that may — in different ways, and to different degrees — pose challenges to comfort and ease of viewing in 3D. Onto this comes the consideration of how HFR technology applies to each of these: what contribution it might have to helping any particular problems that can be identified. For some problems there might be no conceivable contribution at all, which, as noted earlier, is also important to establish. The potential for a complex overlapping of effects here, contributing to a negative whole, is in part why this process of singling-out, issue-by-issue, is considered especially important. Various factors may be different in nature, but also intertwined. They will be presented in an order that should be conducive to the clarification of such relations, where insights build upon each other. Pre-eminence is given to issues pertaining directly to *motion artifacts*, since these are suspected to have particular relevance to HFR. These will be treated first, while other, assorted issues will occupy the tail end of the investigation, before the chapter conclusion. The topic of 3D cinema and viewing comfort has shown itself to be a very diverse one, and the ambition here is to give a reasonably full, cataloguing coverage of it —

so that HFR technology can be evaluated against the total picture it yields. As the various subtopics to follow have been explored for insights into the chapter questions, they will be tied into an overall picture for the chapter conclusion.

Motion blur

Motion blur — the phenomenon introduced alongside "judder", above — should be an appropriate place to begin the investigation. While motion blur can be more or less eliminated in HFR film — without encountering issues with unsmooth motion — it is part and parcel of a standard 24 fps film. Therefore, any viewing problems engendered by motion blur will reflect on the 24 fps frame rate in general. This forms a basic premise for the discussion to follow in this section.

3D films in 24 fps will generally be filmed with the same shutter speed (exposure time) as 2D films — providing a certain aesthetic to the motion, and smoothening the movement from frame to frame. The standard shutter speed for motion pictures is 1/48th of a second — or, correspondingly, a 180 degree shutter angle. (Brown, 2013, pp. 207-208). Stating exposure time in degrees of shutter angle stems from analog cinematography, where various exposure times are achieved by having a rotating disk (shutter) in front of the film that is up for exposure. If this is a half-open disk (i.e. a 180 ° disk), the still images will be exposed for *half* the time they are up for recording. In 24 fps, this becomes 1/48th of a second. (ibid.)

Motion blur may introduce a significant loss of clarity and detail in the picture. Modern, fast-moving action films run the risk of becoming illegible at moments of rapid movement. In an older showcase video for one of his HFR projects, *Showscan Digital,* Douglas Trumbull laments this:

> It's possible that the Showscan Digital process can solve a number of serious problems that have plagued the movie industry since its inception. The whole world has adapted to 24 frames a second, in a movie theater, that's what a movie texture is like, that’s what people expect. Every filmmaker wants to put exciting action up on the screen, but at 24 frames a second, just when you want the most excitement, is when you get the most blur.
>
> (Douglas Trumbull, in video uploaded by YouTube user Vradst, 2010, 0:00:25)

As Trumbull outlines this problem, it is clear that it pertains as much to 24 fps 2D films as it does to 3D. The amount of blur is imprinted onto the still images. There is thus little reason to think that 3D would somehow make this smearing increase or become more visible, as may be suspected with other motion artifacts. (This is treated below, in a later section). There remains a question, however, of whether motion blur may cause any viewing problems specifically for 3D film — and what the mechanism behind this would be, in such a case.

Firstly, motion blur appears to be implicated in *negating* the 3D effect. In the Showscan Digital showcase-video, Trumbull may or may not link motion blur, specifically, with a certain effect where 3D-perception is cancelled — the communication is somewhat unclear. At around 4 minutes and 40 seconds into the video, his voice-over states the following:

> The transition of film production and exhibition to an all-digital medium is driven by 3D. Yet 3D suffers worst from the shortfalls of 24 frames. Aside from the obvious blurring, when frame to frame motion of an object on the screen matches or exceeds the inter-ocular left-eye right-eye displacement, the entire 3D-effect is lost.
>
> (ibid., 0:04:25)

This voice-over is accompanied by the following illustration:

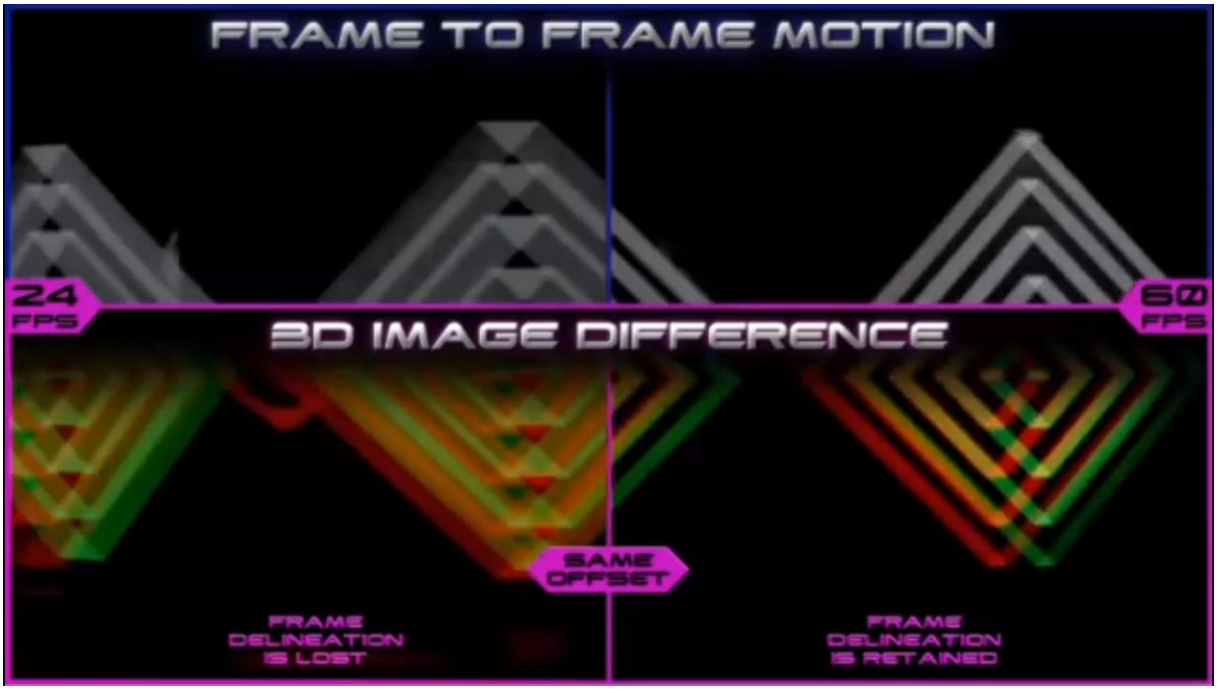

Fig. 1.3: From promotional video *Showscan Digital from Douglas Trumbull* (Vradst, 2010)

These diamond-shaped figures are a form of testing pattern — for 3D images, and the horizontal offset between the two slightly different images that are delivered to each eye in 3D. The one on the left corresponds to 24 fps, and the one on the right to 60 fps. The issue that is pointed to, with this illustration, appears to be one of blur: With 24 fps, the pattern is blurred and not held apart, muddling the otherwise distinct difference between the two retinal images. It seems reasonable that the 3D effect would thus be disrupted. What Trumbull *says* on top of this illustration, however, could garner some complications: "when frame to frame motion of an object on the screen matches or exceeds the inter-ocular left-eye right-eye displacement, the entire 3D-effect is lost". The wording seems, perhaps, to point to an issue distinct from motion blur: the 3D effect being lost when a moving object skips horizontally on the screen, from one frame to the next, *with a length that exceeds the horizontal offset between the left and right images of that object*. (Such skips are longer with lower frame rates, the moving object "reappearing" further ahead from one frame to the next, compared to HFR film). Intriguingly, if the latter alternative approaches the intended meaning, Trumbull appears to be the only source I have found that is specifically calling attention to this phenomenon. Meanwhile, there has been more success with finding corroboration of the idea that motion blur itself cancels or lessens the 3D effect — the investigation of which will be continued below. (This does not seem to exclude the possibility of an additional effect from excessive "frame to frame motion").

Before this, it should be emphasized that Trumbull is referring to *cancellation* or lessening of the 3D effect here, because of insufficient image information in 24 fps — seemingly not a *discomfort/eyestrain* effect, like Peter Jackson evokes in the quote in the beginning of this chapter. This issue of cancellation may be relevant for viewing comfort, but may also fall slightly on the side of this concern — being more relevant for a general increase in quality and impact of the 3D experience. This may also be what is sought after with HFR for 3D — not just a *remedying* of discomfort with the 3D experience, but a heightening and *bettering* of it. We will have to tentatively bring with us this issue of cancellation, at this point — to any ends and conclusions that it might contribute to.

There is motion blur on film, and there is also *spatial* blur — such as that produced by de-focusing the camera. In her handbook on 3D filmmaking, filmmaker Celine Tricart states that the general relationship between 3D depth perception and blur is such that "Perception of volume is inversely proportional to the degree of blurriness. The more an object is out of focus, the more its perceived volume will flatten." (2017, p. 160). While it is slightly

undetermined whether motion blur also follows a similar, gradual pattern of inverse proportionality, it is definitely implicated in "flattening" the perceived volume of elements affected by it. In my aforementioned e-mail correspondence with Matt Cowan, he conveys that motion blurring of objects "probably reduces the ability to place the object in a definite depth plane because there aren't defined edges to fuse. This resolves itself when the object comes to rest." (Cowan, 2017).

There seems to be no indication here, nor anywhere else in my research, of any *discomfort* or *eyestrain* problem — relating to objects going in and out of a salient depth perception, due to motion blur. Interestingly, motion blur is even deemed to *help* the comfort of the 3D experience, through "smoothening" over the gaps in the motion that comes with 24 fps. Matt Cowan relates that "motion blur from a large shutter angle is important to avoid the perception of discontinuous motion - it definitely helps 3D" (ibid.). This would appear to be similar to how motion blur also works with 2D, smoothening the motion, but it might actually be *more* needed when the motion takes place in 3D's privileged depth direction — the "Z"-direction. ("Z" as opposed to the "X" and "Y" directions, the only two dimensions in which 2D film movement occurs). In another e-mail correspondence, with stereographer Ray Hannisian, he offers the following statement on 3D motion in-depth:

> Motion along the “X’ and “Y’ axes are more or less linear. (Certainly, things can accelerate or decelerate.) However, the changes in parallax information as objects move toward and away from the camera, are geometric! An object moving up and down or side to side will experience a “gap”. The amount of change to our 3D perception as objects move closer or farther, suffers more in those “gaps”, as an evolution the of [sic] stereo effect will have fewer pieces to complete our mental picture of an event.
>
> (Hannisian, 2017b)

What happens when a 3D object moves in depth is that the left- and right-eye images of that object actually move in diverging directions, so as to change what is called binocular *parallax* or binocular *disparity*. These are both terms that denote the distance of the horizontal offset between the two images, as well as the slight difference in their appearance, due to being views of the same objects from slightly different vantage points (Howard and Rogers, 1995, p. 2). This gives rise to the impression of different depth placements of the object: in front of the screen, close to the viewer, behind the screen, far from the viewer, and so on. A continual and

rapid changing of parallax thus enables the impression of seeing an object "shoot" into the distance in 3D film, for instance. Owing to the necessary change in distance of horizontal offset, there is an added complexity to such a motion. It may correspondingly pose a more complex task for the visual system to grasp and process the motion satisfyingly. The inherent "gaps", in the flow of information afforded by 24 fps, may then be especially problematic with motion in-depth, because the visual system requires *more* — a reinforcement of information — to process the motion, and achieve the proper sensation of motion in depth. (More compared to what is needed with motion confined to the two-dimensional X-Y plane).

Hannisian (2017a) further conveys, similarly to Cowan, that he finds motion blur directly useful for 3D: "The ghostly blur, or trace of an object's path, actually registers as "Z" axis information. We can see the path that an object has travelled. I find that more pleasant and "natural" looking than a series of "jumps"." If correct, the idea that motion blur actually registers as information about depth movement is quite intriguing — and points up what may be a very subtle overall point on these matters: while both gaps in the motion and blur may constitute a lack of information, leading to problems with placing 3D objects in proper depth, motion blur simultaneously acts as its own kind of information. The visual system may be more accepting of this, as an overall diffused "compromise", in the perception of depth movement.

Contrary to this possible benefit of motion blur, blur has generally been a contentious issue of 3D filmmaking. According to Celine Tricart, it has at times been portrayed as an effect that does not work well within the context of 3D. (2017, p. 160). She modifies this view, however, stating that blur can be employed as a useful device — beholden to the aforementioned rule of inverse proportionality, between blurriness and volume perception. (To note, it is *spatial* blur that is foregrounded by Tricart, although with possible implications for motion blur, as we shall see). While the artistic use of blur may have to be rethought in several ways with 3D (compared to 2D), there is room for its successful use (ibid.). Meanwhile, blur *is* also somewhat precarious territory when it comes to 3D. Too much blur, to a point where binocular disparity is completely negated, can cause significant problems:

> Areas that are completely out of focus can sometimes be very disturbing because they seem to float at the screen plane [the distance of the actual film screen]: The brain fails to detect corresponding points on the retina, so it concludes that this area has no retinal disparity and therefore positions it at the vergence plane.
>
> (ibid., p. 160)

Stereographer Bernard Mendiburu, in his own handbook on 3D filmmaking, corroborates how a *motion*-blurred background can yield this kind of disturbance:

> "You will want to avoid horizontal motion blur because it adversely effects stereoscopic depth perception. When a background is blurred, as in a side shot of a character driving a car, 3D perception is impaired because the horizontal disparities disappear and the image seems to be in the screen plane."
>
> (Mendiburu, 2009, p. 112)

Importantly, motion blur is not subject to quite the same control that a filmmaker can bring onto spatial blur. If an on-screen element moves fast enough, it *is* going to blur to a certain extent, depending on frame rate and exposure time — which is usually set to the standard parameters for motion pictures, delineated earlier: 24 fps and 1/48th second. Speed can be controlled and limited, but may entail a significant curbing of the artistic freedom to put fast motion on the screen. This resonates with the notion that movies based on fast action scenes are a particular challenge for 3D, as indicated by Douglas Trumbull in his promotional video.

Meanwhile, it should be noted that different cinematographic situations may not be equally likely to generate an experience that is "disturbing" in practice — as per Tricart's description. In Mendiburu's scenario, it is plausible to imagine a relatively static juxtaposition of a driver in profile view, on one hand, and a whole, consistent *area* of the shot on the other — within which heavy motion blurring takes place. (The scenery rushing by outside, framed by the car windows). This may correspond to a shot where excessive depth of field keeps a background (or parts of the background) blurred to the point of "flattening" it — and allows time for the viewer to absorb, and be disturbed by, the unnatural discrepancy in depth. It may be less consequential, in this regard, that *isolated*, motion-blurred *objects* — a football flying into depth, for instance — lose their 3D effect, for small amounts of time, as they travel in otherwise voluminous scenery. For these to be re-positioned at the screen pane does not seem to have the same potential to disturb as persistently "floating" backgrounds (or similar visual

configurations), if there is even time to apprehend this loss of 3D placement, for the time that motion blur is severe enough. Also, if more-or-less *everything* in a scene is severely motion-blurred, there should be no discrepancy between elements — leaving only the issue that blur also exhibits in 2D: a lack of clarity and legibility.

3D and the visibility of motion artifacts

As was the premise of the above treatment of motion blur, HFR can also make other motion artifacts effectively vanish. 24 fps, on the other hand, will be beholden to them in one way or another. From a viewing comfort perspective, it should be preferable for these artifacts to occur in a way that does not make them more visible than necessary. While determining the visibility of motion artifacts is only one part of determining the actual problem that they cause to the filmgoer, artifacts are a potential grievance merely for being visible — as seen with the earlier commentary on the opening shot from *Casablanca*. Insofar as *differences in visibility* can be established between 2D and 3D, this could in itself contribute to an account of 3D-specific problems with visual comfort (in 24 fps).

In gaining empirical insight into 3D's relation to the visibility of motion artifacts, as compared to 2D, Hoffman et al. (2011) has made an important contribution — one that appears to stand out for its applicability to the concerns of this chapter. Hoffman et al. predicted that 3D would not contribute significantly to the visibility of artifacts:

> The spatio-temporal filtering associated with stereo visual processing is lower pass than the filtering associated with monocular or binocular luminance processing, so we predict that motion artifacts will generally be equally visible with stereo and non-stereo presentation.
>
> (Hoffman et al., 2011, pp. 9-10)

Put another way, motion artifacts' relation to Watson's model of the *window of visibility*, used by the researchers here, is not significantly altered by the conditions posed by binocular (3D) viewing. This prediction was mostly borne out in the subsequent experiments.

Several differentiated experiments, with viewers watching 3D in motion, were conducted by Hoffman et al. Note again that in the terminology of this study, "judder" chiefly means "discrete or unsmooth motion" (ibid., p. 10.) — *not* the specific "vibrating" manifestation that unsmooth motion has when actively tracking an object. One of the factors being varied in the

experiments was the occurrence of motion *in* depth: 3D that utilized movement in the depth direction, versus 3D that did not. As was mentioned with regard to motion blur above, 3D motion in depth is particularly interesting, because it presents a particularly complex motion percept. Hoffman et al. asked whether this may have an impact on the visibility of motion artifacts: "A stimulus moving in depth creates images that move in opposite directions in the two eyes. Such a stimulus is perhaps more likely to create the appearance of unsmooth motion with binocular than with monocular presentation" (ibid., p. 12). Compared to a 2D version of the same stimuli, 3D depth-motion tended to exhibit slightly more artifacts at low capture rates (frame rates) and slow object speeds, and slightly *less* at high capture rates and high objects speeds. Differences were altogether small, however (ibid., p. 13). Note that object speed and frame rate are factors which work in opposition, to "cancel out" their respective effect on judder and other motion artifacts. Slow frame rates contribute to more artifacts, while a slow speed alleviates the issue — and vice versa. A similar ratio between the two parameters, across fast and slow conditions, is thus generally predicted to yield similar results in the visibility of artifacts (ibid., p. 9).

For 3D viewing where motion does *not* take place in depth, conditions are simpler. No significant difference was found here, in the visibility of motion artifacts, between 2D and 3D stimuli. (ibid., p. 11). Through both theoretical predictions and analysis of experimental results, Hoffman et al. draw toward a conclusion that 3D has little bearing on the visibility of motion artifacts:

> The observation of no clear difference between motion artifacts with monocular and binocular presentation, coupled with a similar finding in Experiment 1, suggests that the predominant source of judder is not in the computation of disparity among binocular pathways.
>
> (ibid., p. 12)

In a later literature review on 3D display technology by Martin S. Banks et al., which included two of the same researchers as Hoffman et al., the findings of the 2011 study (those specifically on 2D-3D differences in artifact visibility) are briefly summarized: "Hoffman et al. observed only a very small increase in the likelihood of observing motion artifacts with binocular as opposed to monocular viewing." (Banks et al., 2016, p. 411). To be noted, no sources objecting to this are cited — although no other experimental studies, confirming the

results, are mentioned either. This particular issue appears to be a novel avenue for empirical research.

An important facet of the study conducted by Hoffman et al. is that participants only reported whether they saw motion artifacts or not (ibid. p. 10) — not the character or perceived severity of the artifacts. This appears to be linked to the "window of visibility"-model employed by the study, limiting its purview to findings that speak to what the model is most capable of predicting. Daly et al. (mentioned very briefly earlier, page 21), seeking in their own work to look beyond mere observability of artifacts, state that this model "predicts only detection performance and does not address the appearance and magnitude of motion distortions" (2015, p. 62). This assertion might be in need of some slight modification: Watson's model can predict whether judder is likely to appear only as a "flickering" or as multiple images, as mentioned (Watson 2013, p. 18), and Johnson et al. (2014a, p. 399) theorize a greater severity of unsmooth motion, based on artifacts' deeper intrusions into the window of visibility. It appears to be generally limited in its ability to account for the particular appearance of motion artifacts, however — which is important to us here, in seeking to tie these phenomena to an overall impact on the practical viewing comfort of the film experience.

The assertion that Hoffman et al. is able to make, from their binary question of observability, appears to be that 3D viewing itself does not have an effect similar to that of *increased contrast*, mentioned earlier (page 26): High contrast levels in the picture can bring the experience of judder into perception — and also into further severity of perception, if contrast is made even starker. 3D does not appear to be significantly implicated in such sensitivity. This, however, does not necessarily give a full account of possible differences, from 2D to 3D, in the *appearance* and/or overall subjective effect of motion artifacts — once they cross that threshold of visibility. Consider the suggestion from Ray Hannisian (2017b) above, that movement in the depth-direction suffers more from the informational gaps of 24 fps, compared to movement that is not in depth. This does not depend on the gaps being more visible, per se, only that their visibility causes different problems (or different *degrees* of problems) under different circumstances.

Following this, there could particularly be a salient opening onto a question of whether visible *judder*, the effect of *tracking* unsmooth motion, could have a specific interaction with 3D — one that spells problems for viewing comfort. Judder is likely to be especially important in a

practical film-viewing context, because "In typical cases, viewers will most likely track salient objects in the scene" (Johnson 2014b, p. 3). While it may enter the window of visibility under circumstances similar to 2D viewing, this does not seem to foreclose the possibility that judder gains a different characteristic or appearance, and perhaps an increased discomfort, in 3D. This will be given a brief treatment in the section immediately below.

3D and judder

While the discussion immediately above spells a potential for judder, to have a special role in making 3D less comfortable to watch, no corroboration of this has actually been found. This appeared, initially during research, to be an interesting possibility — perhaps the source of a factor which alone served to clearly and unambiguously establish eyestrain problems specific to 3D and 24 fps, as referred to by Peter Jackson and others. This has not been borne out in subsequent investigation. It might be useful to consider what this possibility could appear to be, however, and thus also flag the subject for future discussion. Consider the following illustration:

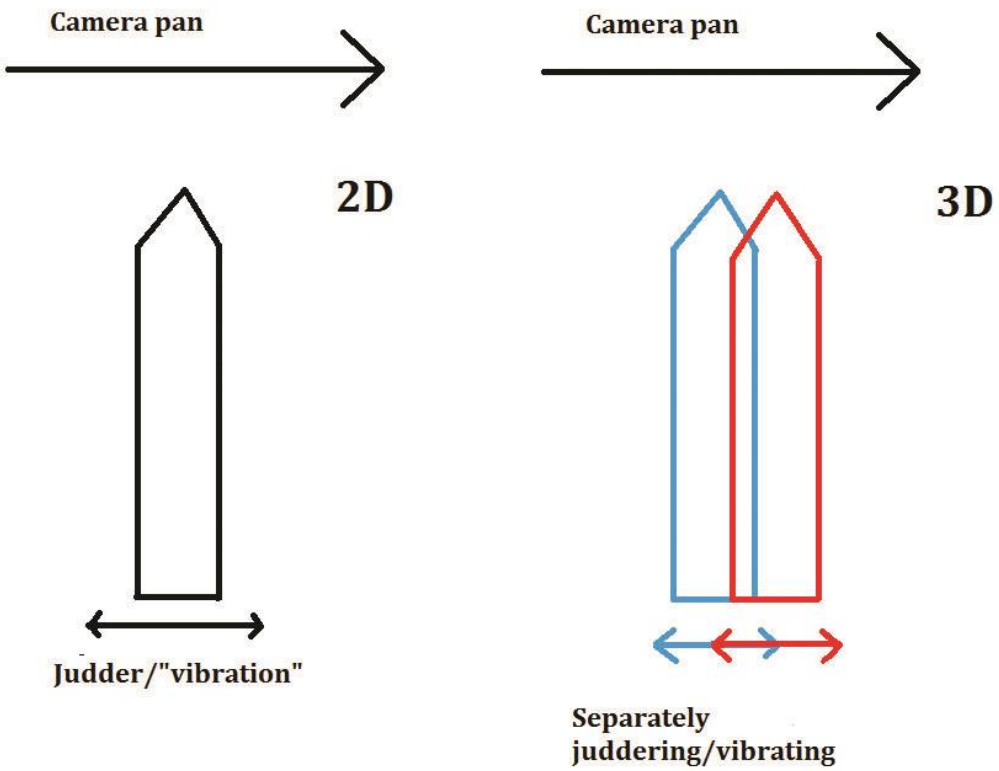

Fig. 1.4: Picket fence slat, illustration of judder for 2D and 3D, author's illustration.

The emblematic case of the horizontal pan across a juddering picket fence is again used here, for simplicity. The pointed figures in the illustration represent one individual slat in such a fence. Judder, as has been described, can be a quite distorting (and disconcerting) phenomenon. With 2D, however, there is only one, single juddering view, onto the single fence slat — the one we assume is being tracked by the eyes. In 3D, there are *two separate views* — two, horizontally offset slats, one for each eye (red and blue in the illustration). Mild cases of judder are perhaps not suspected to be very consequential, since the effect should be mostly one of the juddering object "flickering", while staying in a fairly defined position. We may ask what happens, however, when judder becomes quite severe. The left- and right-eye slats would then "vibrate" significantly, leaving an appearance of multiple, unstable imprints. This would seem that it could have a potential for begetting some particularly problematic percept — and perhaps particular confusions — to the visual system. This suspicion arises from the observation that the slight binocular disparity, that creates the 3D effect, *also* consists of a set of multiple (two) images that are offset in the same direction that the "vibration" here takes place (horizontally). It thus seems possible that the juddering effect might be confused for binocular disparity, for instance — from which viewing discomfort could ensue. We may also ask whether this more complex 3D configuration could contribute to a kind of judder that is simply seen as more "untidy", "jumbled" and/or aesthetically unpleasing, compared to judder in 2D — seen aside, that is, from issues of eyestrain. I have not been able to locate a description of any effect of this sort, however, despite inquiring very specifically for it, in the type of technical literature that is used throughout this chapter, and also in my correspondences with professionals in the field of 3D film. Investigations into this might be fruitfully taken up elsewhere, however, perhaps with different results.

Multi-flashing, dark frames and "edge banding"

The role of the section to follow is, in part, to form a slight caveat to the issues of 3D and the visibility of motion artifacts, treated above. There is one finding of Hoffman et al. (2011) that seemingly does not comply with their general finding that visibility of motion artifacts are equal for 2D and 3D. I have chosen to place this under its own headline, to organize the text and hopefully benefit the reading process — especially since the matters that follow are possibly the most technically "compact" ones that are treated in this chapter. These do not necessarily appear to be of transformative importance, for the overall findings in this chapter — yet they should warrant some acknowledgement and consideration.

In addition to unsmooth motion and judder, Hoffman et al. (2011) make mention of a third, seemingly more obscure kind of motion artifact — "edge banding". Edge banding is described as "more than one edge seen at the edge of the stimulus" (Hoffman et al. 2011, p. 8). It occurs due to particular methods (presentation protocols) for presenting 3D images in contemporary 3D technologies — utilized in cinemas and elsewhere — where the same images are flashed multiple times, and where entirely dark frames occur between these flashes. (This, to be noted, bears a fundamental similarity to the naturally occurring periods of darkness in traditional, analog (2D) film projection — see page 26). Johnson et al. state that "In cases of multi-flash presentations, another effect — edge banding— can occur […] in which repeated presentation of an edge creates the appearance of *ghost edges*." (2014a, p. 393, emphasis mine). This study includes some of the same researchers working on Hoffman et al. (2011), and it appears clear that terminology employed is consistent between the studies, and not a source of confusion.

The industry-standard RealD system for 3D cinema exemplifies such multi-flashing. More specifically, it uses *triple-flashing* (Hoffman et al., p. 4). With 3D there is a *pair* of frames (intended for separate eyes) for each captured 1/24th second of film. RealD interleaves these frames in an alternating succession. If we assign the letters L and R to left- and right-eye views, for individual, captured instances of time in the film (denoted by numbers), the succession can be schematized as follows:

L1-R1-L1-R1-L1-R1 || L2-R2-L2-R2-L2-R2

The horizontal direction is the time direction, here, and the two vertical bars in the middle denote the changing into a new *pair* of images for alternate triple-flashing — captured slightly later (1/24th of a second) by the camera. The joint technology of glasses and projection, in RealD, is such that the left eye is prevented from seeing the right-eye images, and vice versa. What the left eye sees, then, is a darkness "D" for the time(s) that the right-eye images are up for projection:

L1-D -L1-D-L1-D || L2-D-L2-D-L2-D

This flashing procedure, with associated dark frames, is purportedly responsible for that particular artifact termed "edge banding". Edge banding is more commonly perceived when eyes are tracking objects (Hoffman et al. 2011, p. 19). This would necessarily be to say that it takes place alongside, simultaneously to, or *upon* the phenomenon of judder, which is also

salient when tracking objects. Several types of motion artifacts can be present at once (Johnson et al., 2014a, p. 396). Indeed, within the system of terminology that has been laid down for this thesis, it seems reasonable to state that edge banding is a *particular manifestation of judder*, which occurs during presentation protocols which use multiple flashes (and associated dark frames). Johnson et al. provide a very informative figure, schematizing the crucial differences here — as well as visualizing them, in a simplified manner:

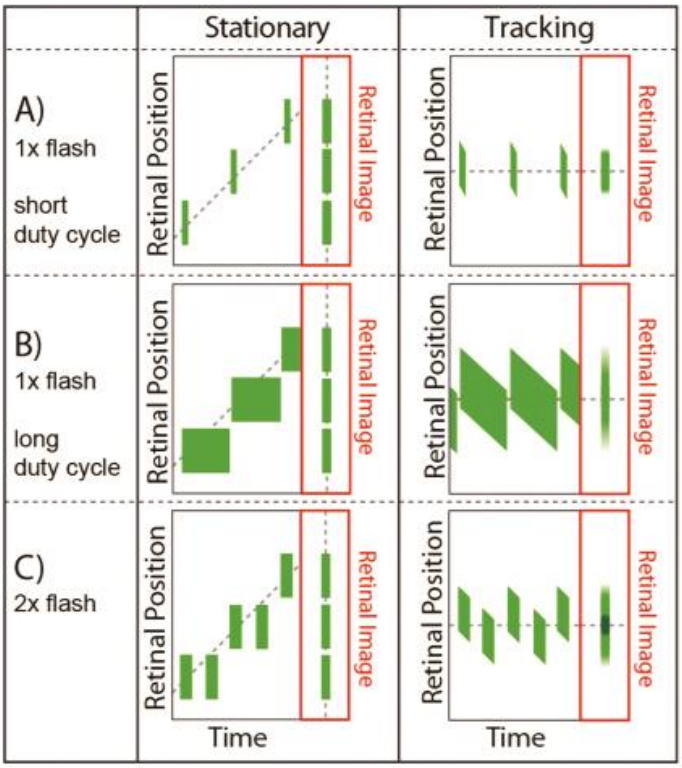

FIGURE 1 — Retinal-image stimulation with different display protocols, with stationary fixation and eye tracking. The left sub-region of each panel shows a time and position plot, and the right region shows a cross section of the retinal image integrated over time. The left panels show the motion along the retina over time when fixation is stationary. The right panels show the retinal motion when the object is tracked with a smooth-pursuit eye movement. A). Single flash (1×), short duty cycle (as in a stroboscopic display). B). Single flash, long duty cycle ~1.0 (as in a sample-and-hold display). C). Double flash (2×), duty cycle ~0.5 (similar to temporally multiplexed S3D display).

Figure 1.5: Figure 1 from Johnson et al. (2014a, p. 394), *Motion artifacts on 240-Hz OLED stereoscopic 3D displays.*

The middle case of judder, B (middle row, right column), has a likely correspondence with the home theater owner's experience of a severely juddering tilt in *Casablanca* — since consumer LCD displays and digital projectors are "sample-and-hold" in nature, with no dark periods, as remarked earlier (page 26). C, however, is a double-flash protocol, and thus has a smaller "duty cycle" — meaning that the image is "on" (visible) for less than the full available

1/24th of a second (in 24 fps), since it gets intermittently flashed. The double-flashing has a duty cycle value of 0.5, in this case, as opposed to the full 1.0 value of sample-and-hold. Note that for the eye-tracking case of C, (bottom row, right column), the positions of retinal images are *slightly offset* against each other, in an alternating fashion. This is not the case for B, where retinal images are perfectly lined up when tracking objects (middle row, right column). Herein, it appears, lays the particular effect of "ghost edges" that are termed "edge banding". Meanwhile, when the eyes are stationary and *not* tracking (all of the left column), none of the above configurations show differences on the resulting retinal image (left row, A, B and C are identical for the "Retinal Image" sections).

With the multi-flash protocol of RealD, we thus seem to have a particular appearance of juddering that is characterized by the specific edge-banding phenomenon, described above. While they may potentially be equally visible, it is not a given that these different characteristics — between judder from multi-flashing, and judder from sample-and-hold — are equally displeasing or discomforting to behold. Recall the earlier mention of "dark periods" in the interstices of traditional film projection, which could help *reduce* judder in the image. While such reduction is not the motivation for having dark periods occurring in these 3D technologies, there should be no reason to believe that they will not provide *the same effect.* While the artifact of "edge banding" and "ghost edges" enters with these dark periods, the net effect may actually be one of a positive trade-off, where pure sample-and-hold judder is the more uncomfortable and undesirable percept. While this may not be entirely settled, it would correspond well with the general assertion that artificial "black data" insertion makes a significant and positive contribution to the experience of tracking motion with the eyes, as held in the aforementioned study by Hong et al. (2005, p. 11).

This, in turn, re-actualizes the question of visibility versus appearance or character of motion artifacts**.** This could have some bearing on a particular finding made by Hoffman et al (2011), in addition to those treated earlier. In one of their experiments, participants were subjected to imagery of an object moving in-depth in a (RealD-type) 24 fps, alternating triple flash protocol — both in 2D and 3D. (2D cannot display a depth percept like 3D does, but the same stimuli, of an object going "in" our "out" of the picture frame, can still be presented in two dimensions). *Exclusively* for 3D, the reportage of visible motion artifacts saw a significant increase (2011, p. 13). Recall that no strong effect, to such an end, was found with the experiments considered earlier. The factors that were altered compared to the prior experiments — multiple flashing and dark frames — appear to be the likely causes of the

change in outcome. Hoffman et al. thereby assert that "there is a purely binocular motion-artifact effect for motion in depth at faster speeds and particularly with triple flash presentation" (ibid., pp. 13-14). Furthermore, they conclude that "Flicker and motion artifacts are generally more prominent with stereo [3D] than with non-stereo displays, but the greater prominence is primarily due to the insertion of dark frames rather than something unique to stereo processing." (ibid., p. 23). This becomes somewhat difficult to interpret, and these two statements seem to contradict each other — motion *in-depth* could well be interpreted as "something unique to stereo processing". In attempting to bring clarity to this, it should first be noted that Hoffman et al. report that no instructions were given to participants regarding eye movements, but that they gathered from informal observation that participants usually *tracked* stimuli (ibid., p. 7) This corresponds with the assertion by Johnson et al. (2014b, p. 3) that this is what viewers tend to do. Owing to the binary answers on visibility provided by participants (artifacts either visible or invisible), there is no data on exactly what kind of artifact gained saliency here, exclusively for 3D viewing. However, with the general likelihood of eye tracking, and multi-flashing being introduced as a new variable, it seems that judder with a particular "edge-banding"/"ghost edges" component is at least suspect in this increased visibility — which, to emphasize, was found to be exclusive for 3D.

If we posit that this greater prominence of artifacts in 3D can be equated with a significantly worse viewing experience, likely that of juddering and edge banding, conclusions may become quite counter-intuitive. As brought up earlier, multi-flashing and dark periods are generally deemed to *milden* judder, and make it more agreeable than the "full" judder of sample-and-hold displays. It may however be that the particular character of "edge banding" artifacts have a particular ability to appear more easily through 3D than 2D viewing — unique among the motion artifacts considered in this chapter — although no mechanism for this appears to be described or indicated.

There is also a question of whether this phenomenon *can* be equated with a significantly worse viewing experience, in the practical context of cinema. When considered two-dimensionally, stimuli moved very slowly in the relevant experiment. Rate of displacement, in each of the individual retinas, was small because motion stimuli for the relevant experiment mostly took place in depth: 0.05 to 1.0 deg/sec. (Hoffman et al., 2011, p. 12). To visualize this, imagine a train travelling directly into the film frame, versus one travelling perpendicular to the camera's view. The displacement of the former train, across the two-dimensional X-Y directions (across surface of the actual screen), will be much smaller than the latter. Those

experiments in the study which tested non-depth motion covered a much greater range of speeds, from 1 to 16 deg/sec — approximately corresponding to the speeds found with television content (ibid., p. 10), which should be comparable to cinema content. This range of very slow speeds differs from those speeds which seem to be mainly contributing to an emblematic case of juddering, blurred action film, for which HFR is suggested as a remedy — as suggested by Trumbull's Showscan promotional video, for instance. It thus seems quite uncertain whether the peculiar effect pointed to by Hoffman et al. here — driven by multi-flashing and dark frames — should in practice be a salient source of problems, for those seeking to improve the viewing comfort of the current 3D cinema experience. Although quite doubtful, this could be in need of some conclusive confirmation or disconfirmation — which is beyond what I have been able to make in the research for this thesis.

Light levels

From this point onwards, and for the rest of the chapter, we are generally moving *beyond* issues that are directly concerned with motion artifacts — and onto other facets of the current 3D cinema experience.

A substantially complicating factor, to the picture of 24 fps 3D and its current state of viewing comfort, is *brightness of projection*. There is a widespread situation that 3D 24 fps cinema projection is significantly dimmer than its 2D counterpart (Belton 2012, p. 192). This is necessarily a significant issue for comfortable viewing. The black periods associated with alternating presentation of images, investigated above, cut the amount of light to each eye. Moreover, the polarization technology for separating left- and right-eye views, in both projectors and 3D glasses, further contribute to light loss (ibid.) The brightness of current 3D cinema may thus fall significantly short of the brightness standard for projection of 2D film: 4.5 foot-lamberts versus 14-16 foot lamberts, respectively (ibid.). (In approximate SI units: 15.4 versus 50-54.8 candela/m^2). This is a discrepancy that could be closed with proper projector settings, and also technological improvements, which is currently foreseen through the industry's adoption of laser light projection (ibid.)

Somewhat paradoxically, to our perspective here, such dimness of 3D film has necessarily been a significant factor in *reducing* the visibility of motion artifacts: With a dimmer picture, contrast in the picture is heavily reduced, thereby reducing the "window of visibility" for artifacts. Insofar as motion artifacts are particularly problematic in 3D, the problem is poised

to open further with improved light levels. This appears to be a significant confounding factor, to the overall picture of where viewing comfort is currently headed with 3D 24 fps cinema. The near future could provide some needed clarification, with a more widespread adoption of projection equipment which remediates 3D's current brightness issue. One future scenario could be a significant overall improvement to audiences' appreciation of 3D, which is the likely hope of industry actors working to usher in brighter and better projectors. One promotional text from projector manufacturer Christie Digital, for instance, reads as follows:

> 3D box office sales have been on a steep decline since 2011. Learn how Christie 6P laser projection is set to redefine the 3D cinema experience and help exhibitors boost premium 3D ticket sales. Unprecedented brightness, image uniformity and viewing comfort are just some of the advantages.
>
> (Christie Digital, 2014)

It does not seem impossible that screen dimness accounts for a significant bulk of the problems with 3D that are most salient to audiences. A picture that is too dark has very clear implications for viewing comfort. On the other hand, the motion artifact-issue here signals the question of whether the net benefit is at risk of being significantly offset — pointing up the significance of investigating artifacts' interaction with 3D.

3D temporal asynchrony

While 3D camera setups capture left- and right-eye images at identical points in time, current standard 3D projection presents them slightly out of sync. Recall the previous examination of the RealD 3D protocol:

L1-R1-L1-R1-L1-R1 || L2-R2-L2-R2-L2-R2

As before, the horizontal direction here is representative of the time direction, and individual letter-number combinations are individual frames being flashed on the projection screen. Although all the frames bearing the number 1 are from the exact same point in time, as captured by two cameras, they are projected in slight asynchrony: for every instance (three times) that L1 is flashed, the right eye is blind to the view R1 — while it actually belongs perfectly in time to L1 — and vice versa. This asynchrony is potentially a cause of perceptual distortions, described by Hoffman et al.:

> For example, in stereo broadcasts of World Cup soccer in 2010, a ball kicked along the ground would appear to recede in depth when moving in one direction (paradoxically seeming to go beneath the playing field!) and would appear to come closer in depth when moving in the opposite direction. This speed-dependent effect can be quite disturbing, so it is clearly useful to understand what causes it and how one might minimize or eliminate it.
>
> (Hoffman et al. 2011, p. 16)

Experiments found that with protocols where temporal offset was less (i.e. switching faster between corresponding left and right views), distortions also lessened (ibid. p. 15). Higher frame rates should generally be able to contribute to a projection setup where this switching speed is made faster, placing the temporal asynchrony further into negligibility. The current protocol of RealD 3D makes use of 144 flashes per second overall (RealD, 2018), meaning that the alternations between L1 and R1 (etc.) in the above schema have a speed of 1/144th second. This is rather fast, and ensures that distortions are at least much less prominent than they otherwise could have been. 144th of a second is not quite fast enough, however, according to Matt Cowan — who as mentioned was involved the development of the technology:

> This does have a detrimental affect on the viewing situation [...] and it does present some discomfort in most movies. Does the 3D experience overcome this? often. Would it be better if this effect didn't happen? certainly.
>
> (Cowan, 2018)

Douglas Trumbull's *Magi*, a so-called "process" (borrowing analog photographic terminology) for cinematic 3D images from production to post-production, claims to solve this problem through capturing images "time-sequentially", in the same asynchronous fashion that they are to be displayed. (Chinnock, 2017). Another, very certain solution is to employ two projectors at once. IMAX 3D presentation already does this, for instance. (Boffard, 2011) Two projectors could prove quite forbidding in economic terms, but certain projector technologies, such as those utilized by Sony, can show two images at once (Sony 2018). At any rate, the issue seems ripe with possible solutions. These *can* make use of HFR, but do not appear to depend on it. It is also noteworthy that a non-HFR solution of the problem can yield a significant benefit for the viewing comfort of 3D cinema, as indicated by Matt Cowan — in

its current 24 fps state.

Accommodation-vergence conflict

According to a literature review by Marc Lambooij et al., a phenomenon known as the *accommodation-vergence conflict* is often mentioned as a factor for 3D viewing discomfort (2009, p. 1). Under normal viewing conditions, two processes work efficiently in tandem to bring both near and far objects into focus. As the eyes converge upon a near object (vergence), their lenses change their refractive power accordingly (accommodation). A mismatch between accommodation and vergence arises, however, with the presence of a screen. The screen acts as its own cue for how the eyes should adjust. Accommodation remains fixed with the screen, while the stimulus for vergence fluctuates — depending on the specific depth cues presented on the screen (ibid., p. 5). The visual system is able to override the accommodation-vergence linkage — but not without a certain conflict, which is cited as a cause for eyestrain and discomfort (Banks et al, 2016, p. 415). HFR seems to have no apparent bearing on this issue, or any solutions to it. The overall issue has been found to be less likely to cause discomfort at viewing distances typical of cinema and television, however (ibid., pp. 417-418).

Large disparities, frequently changing disparities

More generally, *large disparities* between retinal images can be a source of discomfort. (To recapitulate, retinal disparity is the horizontal distance between the two images that together make up a 3D image). Lambooij et al. (2009, p. 7) assert that visual discomfort in this regard should *not* occur within a "zone of comfortable viewing", which is defined as a retinal disparity below 1° of visual angle. (Visual angle is a means of specifying the size of this horizontal offset, as it appears on the viewer's retinas — as opposed to the actual offset on a movie theater screen, for instance). The limit of 1° should also keep disturbances from the accommodation-vergence conflict at a level where perceptual annoyance is avoided (ibid., p. 12). Even within this 1° zone, however, "visual discomfort might occur as a consequence of much variation in screen disparity (ibid., p. 7). Here, we may imagine a 3D shot where an object moves quickly in the depth-direction, back and forth, or a scene which cuts rapidly between different depth configurations. In the former case (the single shot), one could perhaps ask whether a more rapid updating of depth information, afforded by higher framerates, can somehow ease the transitions. It appears, however, that the key issue is the physical exertions

made by the eyes to change between markedly different states, corresponding to different depth planes: "It seems that visual discomfort increases when the demand on the oculomotor system increases" (ibid.). HFR does not seem to be implicated in this.

Motion sickness

Motion-sickness, or "Visually Induced Motion Sickness" (VIMS), is also pointed to as a potential factor in 3D viewing discomfort. In a 2011 review on potential hazards with viewing 3D television, Peter A. Howarth states that "VIMS comes about when the movement of an image gives rise to vection, the feeling of self-motion in the absence of true movement, leading to symptoms like those of true motion-sickness" (Howarth, 2011, p. 114). VIMS symptoms could be expected to arise from viewing "any film, or television programme, which provides an appropriate stimulus" (ibid.). With 3D viewing, it has been shown that VIMS symptoms are reported to be aggravated when an object on screen moves in the depth direction — as opposed to in two dimensions, across the plane of the screen (ibid., p. 115). Motion sickness is here presented as a complicating factor, in determining why 3D causes discomfort (ibid. p. 115). This mirrors a general concern of this chapter: The sheer range of possible issues with both 3D and 24 fps, which confounds the view onto exactly what role HFR can play in providing a more comfortable experience. Interestingly, with motion sickness, it seems that this problem could be *aggravated* by a more "visceral", "realistic" experience of motion in-depth, which is possibly what is enabled by HFR's reinforcement of temporal information in the image.

3D Glasses

The wearing of the physical glasses involved in 3D is somewhat of an outside factor to the plethora of purported issues with 3D, but could warrant at least a mentioning, to round off this investigation into the contemporary 3D cinema experience. In a study conducted by Jenny C.A. Read and Iwo Bohr (2014, p. 1140), on user experience while viewing 3D TV, it is reported that 8% of study participants may have responded negatively to 3D-viewing either through a nocebo-effect or *discomfort from 3D glasses*. Without attending specifically to these findings here, they resonate with more anecdotal reports that audiences find the wearing of 3D-glasses disagreeable. Needless to say, HFR is entirely outside of the realm of any such issue. It his however interesting to note that discomfort around the eyes, from un-ergonomic glasses, might blend with or be mistaken for discomfort related to the actual viewing of 3D

content — providing further demonstration of just how layered and multi-faceted this overall issue of discomfort may be. Whether this might be a widespread, significant issue or not, technological and ergonomic improvements should be poised to nullify such an issue.

Conclusion

Somewhat surprisingly, problems of viewing comfort with 24 fps and 3D have been more elusive, and harder to pin down, than what the introductory quote by Peter Jackson suggested. At the least, we have established motion blur to affect the effectiveness of, and possibly *negate* the 3D effect under some circumstances. This could make HFR attractive for being able to produce a more emphatic and consistent 3D effect in movies, under some circumstances — but appears to in itself only constitute an avenue for improvement, not a solution to a more pressing problem of viewing discomfort. While this chapter took viewing comfort as its particular focus, the investigation into this quickly elicited this adjoining issue of the quality and consistency of the 3D effect. This definitely also plays into an overall view on the *benefits* of HFR, the base concern from which this chapter emerges. This factor should therefore be brought along, in the consideration of an overall picture with regard to the main research question.

Meanwhile, motion artifacts have not been found to pose a 3D-*specific* problem to viewing discomfort: A problem, that is, which clearly transcends the issues that these phenomena already pose in 2D. To specify, and emphasize: no strong, clear mechanisms have been found whereby these motion artifacts — *or* other traits of 24 fps — are shown to *combine* with 3D, so as not just to *decrease the impact* of the experience, but also to *disturb it.* If these are actually to be found, in spite of the investigation undertaken in this chapter, it appears that they are in need of being communicated much more clearly than what is currently the case.

Meanwhile, the problems that 3D already poses to viewing comfort can complicate the overall picture significantly. One way to regard 24 fps as particularly problematic, in conjunction with 3D, is in the sense that the *accumulation* of problems — inherent to both factors — lends itself to a sum total "unacceptable" quality of viewer experience. While this does not quite cash out an idea of these factors *combining*, to elicit something particularly objectionable to the viewer, it is a fair take in itself: anything that could make the experience *better*, overall, could be desirable to introduce. This position would also not depend on whether there are remaining issues with 3D that HFR cannot solve, and for which no other, clear solution is

apparent — which there are some indications of: The observation that *rapid cutting* can pose a problem (page 47), due to rapid changes in binocular disparity between shots, is quite interesting in this regard. Rapid cutting would appear to be part and parcel of the action film experience that is particularly sought remedied by HFR, for its issues with blurring and judder.

While HFR could bring significant improvements to the overall experience, it may face unique obstacles, as compared to other technical innovations. (These obstacles, then, are to be treated in the later chapters). These may hinder it from being introduced simply for "good measure" — as what may be the case for an improved sound system, for instance. The industry's willingness to brave these obstacles may depend on the *magnitude* and the *exclusivity* of HFR's ability to bring significant improvements. Magnitude remains quite high, in spite of the above conclusions — but could be significantly higher if HFR was found to solve a particular, pressing problem of viewing comfort, engendered by the combination of 24 fps and 3D. Meanwhile, 3D's issue with *low light levels* stands out for its potential as one major angle of comfort improvement, and does not depend on HFR. Solutions for this appear to be on the cusp of realization, with projector technologies currently entering the market. If the main concern is to simply reduce the accumulation of problems, or offset it with other benefits, screen brightness may be set to make a powerful impact. This is also just one part of a repertoire of currently known, potential improvements, where HFR may be implicated, but not necessary — such as correcting the RealD-system's asynchrony in image projection (page 45).

Where 2D HFR appears to stand in this, is a position where HFR's benefits have somewhat of a lesser magnitude than in 3D, but not as drastically as one might initially expect — with the apparent elusiveness of a 3D-specific "special" factor for viewing discomfort in 24 fps. Motion artifacts, particularly judder, can be quite an unpleasant part of 24 fps, as has been explored. HFR can thereby bring a considerable benefit through its elimination. Also, HFR in 2D may be considered to have an added "master" benefit, in being able to cover and alleviate virtually *all* salient problems of visual quality and comfort, inherent to the 2D 24 fps format — pertaining, as these are, mostly to the visibility of motion artifacts. This would presumably make way for a supremely friction-less viewing experience. Although on slightly different terms, and different levels, HFR would thus be a considerable boon in both 2D and 3D — and no other innovation is likely situated to bring a wholesale remedy to motion artifacts, in both formats, like HFR is. However: if we posit a future scenario where HFR continues to be met

with backlash over its aesthetics, and there is an attempt to force the issue of its adoption, a "viewing comfort"-argument for this may not be quite as strong as it could initially appear to be.

CHAPTER TWO: HFR and convention

Introduction

With chapter one having given viewing comfort its due, chapter two will turn to issues of HFR and stylistic *convention* — conventions of cinema, and also of other categories of audiovisual media. At face value, the backlash to the *Hobbit*-trilogy's HFR aesthetics appeared to have much to do with a defeat of conventional expectations: expectations for genre, as genre pertains to the appearance or "look" of moving pictures, expectations for the "cinematic", and more. This may be summarized as the defeat of expectations to be re-immersed in a familiar set of visual conventions — of the sort exemplified by Peter Jackson's precursory *Lord of the Rings*-trilogy, but also, to a degree, by cinema itself.

Observations that *The Hobbit* in HFR did not look like "film", leaving aside further allusions to what it might look or feel like instead, are open be taken quite straight-forwardly: However else it may be described, the 48 fps version of *The Hobbit* looked markedly different from the 24 fps version. Joining such judgements, however, is a rich and diverse pool of assessments of what overall effect, more or less exactly, the HFR format had: Rather than film, *The Hobbit* may have looked like a soap opera, a television play, documentary footage, live sports TV, video games, and yet other points of reference. Notions of *realism* crop up also: HFR film conferring a sense of being "*too* real" — as if watching actors on a set, holding props and wearing costumes, instead of seeing film characters in an alternate world. As a part of this, the enhanced image fidelity and clarity of HFR purportedly also exposed the material unrealism — the "fakery" — inherent to film production. To sample such reactions, we may look to the work of Carolyn Michelle et al., studying the reception of the first *Hobbit*-film, *An Unexpected Journey* (2012). Contrary to the picture suggested above, the largest group of study respondents was in fact found to be "generally extremely enthusiastic about the film" — which is important to note, to indicate that reactions were indeed "mixed" (as described in the introduction), not uniformly negative. Some praised "the quality and realism conveyed by the film's CGI and other visual effects, using words such as 'fantastic!', 'flawless' and 'outstanding'" (Michelle et al., 2009, pp. 237-238). Others, however, were not so enchanted:

> … a perceptible visual disjunction between real-life footage and digitally rendered characters, objects and settings further undermined believability and led some to compare watching *The Hobbit* to watching a video game, actors in a play, a ‘making of’ documentary, HD children’s television programme, or ‘cheap Brazilian soap opera’
>
> (Ibid., p. 242)

As seen in this quote, beyond the reportage on viewer responses, there are also causal connections being suggested for this effect. Michelle et al., interpreting their respondents' interpretations, afford considerable weight to the increased detail and clarity of 48 fps HFR — leading the format to draw attention to "the constructed artifice of film", creating "a more visible disjuncture between that which was real and that which was fake" (ibid.). We find the same perspective with David Wagner (2017, p. 217): "Since we expect blockbuster cinema to offer visual stimulation and magical attractions, its success lies in concealing the machinery that creates the magic". Julie Turnock, on the other hand, levies more attention on the cultural prestige of film and its aesthetic over other genres or forms of media, and the "quasi-televisual codes of realism triggered by HFR" (Turnock 2013, p. 45). Such codes relate to, but may also stand apart from the quantitative increase in picture information that is enabled by the format. Seemingly closer to Turnock's perspective is also John Belton's, seeing HFR cinema in light of André Bazin's notion of the "ontology" or "psychology" of the image (Belton, 2014) — the intuition of a certain reality status of the depictions in photographic images, extending to moving photographic images: a status as having occurred in the past versus transpiring in the present, for instance.

Out of the fairly small amount of scholarship that has already been done specifically on contemporary HFR cinema (and mostly *The Hobbit*), these contributions have stood out as particularly relevant to the topic of this chapter. They tend not to delve very deeply into how some of the peculiar viewer responses in question may be created, however — centrally, how lavishly produced, million-dollar cinema still manages to court an impression of soap opera or television. This presumably owes to the visual stylistic characteristics of HFR, and possibly also everything else that is transpiring on-screen. It seems pertinent, then, for my own research, to ask: How may we understand and make further sense of the phenomenon at hand, and the conditions driving it?

Chapter questions and structure

- What role do stylistic traits and conventions of moving images play, in forming audiences' apprehension of various audiovisual *genres*, when viewing HFR film?

- What role do stylistic traits and conventions of moving images play, in forming the audiences' apprehensions of *realism* when viewing HFR film? How does this relate to genre?

- Did the *Hobbit*-trilogy's increased image fidelity, due to HFR, expose the material fakery of movie production (sets, costumes, props, make-up, CGI)? How significant was this, in the overall issue?

I will begin the chapter with a treatment of the televisual genre of *soap opera*. The soap opera has, through my research, turned out to provide a useful and informative entry into many of the ideas and topics that are relevant to chapter two. From an exploration of these, I will continue into a shorter engagement with two televisual works: the prime time soap opera *Dynasty* (1981-1989), and the BBC historical drama *I, Claudius* (1976), These will be used to probe various conditions for aesthetics associated with film on one side, and TV and video on the other. Ultimately, two works of HFR cinema will be investigated, in light of the ideas activated prior in the chapter: first, Ang Lee's *Billy Lynn's Long Half-Time Walk*, released in November of 2016, and last, *The Hobbit: An Unexpected Journey*, the first installment in the *Hobbit*-trilogy.

The Hobbit has a tendency to universally frame the discussion of the topic at hand. This is not too surprising, considering that for quite some time, it had a claim on being the sole wellspring of the contemporary discussion of HFR cinema. The picture has slightly shifted, however, with the release of Ang Lee's film in late 2016. The film's drastic 4K-resolution, 3D *120* fps format only found its way to an extremely minimal amount of theaters — only two in the entire U.S. (Sneider, 2016). A wider array of select theaters screened a 2D 120 fps version, however (ibid.), and a Blu-ray 60 fps 2D version is currently available on home video. While 3D may only have been left out due to bandwidth-constraints, these would still mark the first contemporary film releases where a motion picture is presented in 2D HFR — which is somewhat intriguing, considering the overall focus on HFR for 3D. As we will see, *Billy Lynn's Long Halftime Walk* is a starkly different film from *The Hobbit*, a trait which

may prove instructive.

The soap opera

Out of the plethora of genre comparisons suggested above, why pay closer attention to the soap opera, in particular? Firstly, it appears to be a particularly common one out of those comparisons, as well as a particularly "damning" one: If we posit that the high-profile Hollywood movie occupies a maximum, on a scale of prestige in audiovisual entertainment, one might be inclined to place the soap opera on the very opposite end of that spectrum. This dissonance, and its corresponding intrigue, is enhanced by how wildly a film such as *The Hobbit* differs from soap opera — in its aesthetic commitments, circumstances of production, budget, and so on.

Furthermore, this comparison to the soap seems to very easily pass muster without much elaboration. There appears to be a sense of tacit understanding of what is being referred to, even as reportage eclectically alludes to soap operas by various bygone *decades*: “Some viewers have said that “The Hobbit” has the harsh video shimmer of a 1980s soap opera” (O’Hehir, 2012), or “Will The Hobbit Look Like a 70s Soap Opera at 48 FPS?” (Hession, 2012). I am, at least initially, not inclined to think that such vagaries of public discussion track any decade-by-decade history of aesthetic evolution in the soap opera, or other television genres. It might be beneficial to offer some resistance to the overall automaticity of labelling, however. Even as academics evoke the soap opera, specifically with regard to this topic, it has a tendency to be quickly mentioned and glossed over. John Belton (2014, p. 8, 2017, p. 401) twice offers his impression that the look of *The Hobbit* can best be described as that of a "soap opera on steroids". How this impression might emerge, specifically within *The Hobbit*, is not treated much further — beyond asserting a connection born out of frame rates. It seems both timely and interesting, then, to extract the "soap" genre-association from this topic, for more elaboration and scrutiny. This is terrain that could benefit from a slower and more meticulous traversal than may have been offered to date — and should also point beyond the soap, onto everything else "televisual" which *The Hobbit* appears to have called to mind in audiences. To begin this, we may ask: What does soap opera *look like*?

Soap opera style

In terms of visual style, the televised soap opera owes much to the "invisible style" of classical Hollywood. In *Speaking of Soap Operas*, Robert C. Allen deems soap opera style as representing the "crystallization of a set of stylistic conventions taken over from Hollywood filmmaking". (1985, p. 64). One important difference from Hollywood lies in editing style, however — in that the soap opera has typically been edited at the time of recording, by switching between different cameras in a multiple television camera setup. This is an inheritance from soap's live-broadcast past. While different from film practice, this real-time aspect may contribute to soap opera style attaining an even stronger illusion of "invisible" or transparent style than Hollywood films (ibid., p. 66).

At the same time, Bernard Timberg (1983, pp. 1-2) warns us of succumbing to a "realist illusion" where the camera is taken to merely record the narrative in utilitarian fashion. Stylistic features can be discerned, beyond bare pragmatism. Soap operas may display an "intense, intimate camera style", combining close-ups with slow, inward tracking movements and "slow, elegiac movements in and out of the action (ibid.). As is a typical feature of television at large, where screen sizes traditionally have been small, the close-up framing is a mainstay of soap. Together with the two-shot, where two characters are seen at once, the close-up is a basic element on which soap opera style is built (Allen, 1985, p. 71).

Also highly characteristic of soap is the prevalence of interior scenes: "It is commonplace to refer to the soap opera as a world of interiors" (ibid, p. 65). Soaps also typically employ a "necessarily flat television lighting style" (ibid, p. 69). Together with factors such as time constraints, such necessity likely stems from the need for more uniform lighting on television sets, so as to facilitate multiple cameras shooting in different directions at once.

To provide an exhaustive list of the many facets of soap visual style is not feasible here, but a preliminary overview of some key aspects should be useful to bring over to a consideration of cinema and HFR. One final such aesthetic feature, that is expected to be important to our discussion, is the use of *video* (as opposed to film) cameras in soap opera — and in television in general. (Traditionally, this meant video cameras shooting on video *tape*. Today, the digital video camera and digital storage media are likely to reign supreme). It is a strong initial suspicion that we saw HFR received negatively, to one degree or another, on account of

exhibiting aesthetical features resembling those of video recording (conversely, features that do not satisfyingly resemble film).

Jeremy G. Butler (1986, p. 58) calls our attention to the significance of video tape as a recording medium for the soap. Here we find, importantly, the idea of the genre demonstrating a *liveness*-effect, which Butler connects to the use of video formats: a sensation of images unfolding in the present — in the midst of television "flow" — as opposed to being a recording of something that "has been" prior to viewing. The idea that a news broadcast exhibits this effect may be rather intuitive, with its incessant reinforcement of "present reality", in all aspects of production. This specific acknowledgment of soap appearing "live", however, despite having (mostly) left live broadcast behind, could be somewhat less so:

> Because they are recorded on videotape, soap operas more closely resemble television news "actualities" (videotape of news events) than they do nighttime serials and feature films, which are both shot on 35mm film. This resemblance to what television marks as "reality" supports John Ellis's contention: "television presents itself as an immediate presence.... Television pretends to actuality, to immediacy; the television image in many transmissions (news, current affairs, chat shows, announcements) behaves as though it were live and uses the techniques of direct address." [Ellis, 1982, p. 106] Ellis believes that television lacks Barthes's "photo effect," that effect of "present absence" - a presence that is now past - which is generated by the photographic and cinematic images."
>
> (Butler, 1986, p. 58)

To the voices cited by Butler here, we might also insert André Bazin's concept of the "ontology" or "psychology of the image", which John Belton (2014, p. 234) activates with regard to HFR cinema: Spectators play a role in investing the still photographic image with certain values, such as a certain impression of "reality" — a "present tense", a "pastness" or a "present absence". This, in turn, can extend to a similar consideration of *moving* photographic images, according to Belton (ibid., p. 235). For Bazin, according to Belton, this nature of photographic images does not inherently reside in the images themselves — rather, differences are perceived and identities constructed by a spectator situated within a "phenomenological field" (ibid.). "Phenomenological", to be noted, is Belton's own evocation, not Bazin's. Belton's use of the term seems general — not necessarily beholden to particulars of what "phenomenology" constitutes, within the branches of the philosophical discipline

bearing that name. I take it, however, to point toward the *immediacy* with which these sensations and apprehensions of images arise: The pastness of photography or presentness of television that is felt, potentially, is felt prior to any conscious reasoning — like the mood of a musical chord. Rather than being preoccupied with what televisual and cinematic (photographic) images may "actually be", in and of themselves (which the term "ontology" could suggest), this appears to be a useful perspective for the purposes of this chapter: maintaining a focus on spectators construing these immediate intuitions for themselves, as they draw on various salient factors of the media experience at hand.

As glanced from the above quote, Butler briefly points to the visible presence and appearance of the video format in itself — as compared to 35 mm film — as one such salient factor. Regardless of how a video camera is used, where it is pointed and what it is pointed at, there is a certain texture, a certain "look" to video images. This issue of a basic "texture" or surface character, one that differs between film and video, is a subtly complex one. An exploration of this will be made further below — where designations such as "texture", and what it may encompass, are considered.

Beyond such generic, inherent features of the video image, there may be further formal characteristics of soap opera — engendered by the practical circumstances of a television-style shooting situation, for instance — that contribute to a sensation of images being "live". Analyzing the soap *As The World Turns* (1956-2010), Butler shows how a varying haphazardness of close-ups, "awkward" framings and other cinematographic "unorthodoxies" are present (1986, p. 59). These may be seen in relation to the aforementioned *live editing* method of soap, which relinquishes some of the exacting control that filmmakers have over their images, both during shooting and editing. (This is a perspective somewhat contrary to what has been suggested here until now, in focusing on soap's *similarities* to classical Hollywood). Such stylistic awkwardness, according to Butler, functions to "confirm the immediate presence of the televisual image" (ibid.) — our psychological apprehension of the images as unfolding "in the present". Importantly, this suggests the idea of various stylistic features, which may or may not be evident in a given scene or series, strengthening or securing the tendency toward a perception of "liveness" — for their reinforcement of what "television marks as reality", in the wording above. They are further factors within what Belton terms a "phenomenological field". We may perhaps also, from this, gain a converse suggestion of stylistic features *loosening or* de-securing an apprehension of a liveness-effect. Meanwhile, the groundwork for such an effect may already be laid in the fundamental

appearance or "texture" of images captured through video. Also, while attention is here being called to an "undisciplined" use of classical film language, which may threaten stylistic "invisibility", it stands to reason that part of what identifies *As The World Turns* as distinctly soap-operatic and televisual *remains* those hallmarks of that language: the close-up, the two-shot, the "shot-reverse-shot", and so on.

Owing to the sum of these traits, *As the World Turns* may, following Butler, be *especially* inducing of a sense of watching something that takes place "live". In extension to this, I would suggest that it could also be especially inducing of a sense of watching "soap opera" — related sensations of *genre in itself* may be carried in the same sweep of spectatorial experience. We may thereby perhaps even look past the notion of liveness, and look directly to understanding of genre: something is intuited as a soap opera, while something else is intuited even stronger as a soap opera — owing to a distinct televisuality in its stylistic repertoire, for instance.

If we follow such an idea of gradation — of how evocative of the soap opera a given example of the genre is, stylistically — we may also entertain the idea of a corresponding *spectrum*, on which different works in the genre fall on different parts. *As the World Turns* may fall on one end of it that is considered the most "soap-operatic", based on Butler's account. American *prime-time* soaps such as *Dynasty* or *Dallas*, on the other hand, would likely have to be placed on the opposite end — one that is considered the least soap-operatic, and perhaps more "cinematic". These two series are both shot on 35 mm film (IMDB 2017a, 2017b), which should not only help confer a basic, filmic surface character upon the images, but also lead the methods of production away from the televisual. (Editing cannot be done live with analog film, for instance). According to Jostein Gripsrud (1995, pp. 44-45), *Dynasty* was "produced like any feature film technically", with one of the directors involved, Curtis Harrington, describing his work as "classical", "correct". The notion of such an accommodating spectrum of soap opera, and its stylistic-aesthetic range, opens up to the idea of also placing decidedly *non*-soap-works on an extension of said spectrum — asking whether particular motion pictures are more evocative of soap opera than others, for instance, despite generally appearing to be situated far from the genre. This is a perspective that will be brought onto the consideration of specific expressions of HFR-film, later in this chapter.

Before this, however, there is a need to examine the issue of the fundamental "texture" that various recording media bestow upon moving images — that which may give *Dynasty* a basic

"film-look", for instance. While adjoining stylistic features may be quite important, as suggested above, these more fundamental facets of moving images are suspected to play a very strong role in forming the kinds of audience receptions that are of interest in this chapter.

Conditions for film- and video-aesthetics

To assist in the following examination of the visual characteristics of recording media, and related parameters, I will briefly highlight two specific works of television. These differ in many respects, but not least in their means of photographical capture: The aforementioned prime time soap *Dynasty*, shot on film, and the BBC historical television drama *I, Claudius*, which was shot on video tape (IMDB 2017c).

Dynasty is an example of soap opera that is expected to exhibit a “film look" — at least in some facets, by virtue of being shot on film. The slight subversion here — of the idea of soaps having a "soap opera look" — should prove an instructive case to explore, in order to discern between differing aesthetic issues. Meanwhile, the video cameras used in *I, Claudius* appear to offer us an aesthetic congruent with the “soap opera look" — perhaps serving to push one’s conception of royal family intrigue in ancient Rome toward that of the soap. Actors involved reportedly compared the mini-series to long-running British soaps *EastEnders* and *Coronation Street* (Harrisson, 2017, p. 286) The selection of this work is also inspired by journalist Devin Faraci’s (2012) use of it in a very early assessment of the HFR in *The Hobbit* (also relayed in Turnock, 2013 p. 30) — upon seeing a short press preview of *An Unexpected Journey*. The elaborate costume work of *I, Claudius* production may be an additional factor that accounts for associative ties to *The Hobbit.*

Dynasty

Initially, as is often the case today, YouTube provided an initial hunting ground for appropriate video material to analyze. A clip of *Dynasty* which presented itself, in relatively sound image quality, involves the character Steven Carrington (Jack Coleman) confronting his father and the rest of his family with his sexual orientation. The clip comes from season two, at about 40 minutes and 40 seconds into the (penultimate) 21st episode, *The Two Princes* (1982). The specific subject matter should not be important here — it does make for a scene of intimate, intense emotional dispute, perhaps emblematic of the soap opera. I will hold slightly on to the "sub-optimal", online-streamed viewing situation here, because it could

itself be illustrative of some relevant points to follow. (The particular YouTube upload is found in the reference list: Mega Carrington, 2009).

Fig. 2.1: From *The Two Princes* (1982), episode 21, season 2, *Dynasty* (1981-1989)

On the whole, the clip appears to bear out Gripsrud's (1995, p 44-45) suggestion that *Dynasty* lies stylistically very close to the classical Hollywood film. It may reasonably have a claim on being mistakable for actually being one. The camera subtly but actively follows actors moving and changing position, in fairly elaborate patterns, suggesting a developed "blocking" of the scene — i.e. the planning of the actor's movements in relation to the camera — consistent with Hollywood practice. A prevalence of strong close up shots, appropriate to television screens, could perhaps help betray a different context than feature film — but not overtly so. Meanwhile, a correspondence with Bernard Timberg's account of soap opera cinematographic style also appears sound: a "close-up camera style", employing frequent track-ins, having "the effect of bringing the viewer closer and closer to the hidden emotional secrets soap opera explores" (1983, p. 1). The camera tends to softly "push in" on the close-ups of Steven, particularly, whose psychological and emotional makeup is emphasized among the characters in the scene.

Important to note is that features such as meticulous "blocking" (and its associated camera movements) is also a salient factor in an overall recognized aesthetic of cinema — a film "look" — even if it is at a certain remove from issues of camera and recording technology,

more central to our concerns here. Contributing factors here are not reducible to a range of limited, technical choices. Similarly to what was suggested with Butler's account of a decidedly "live"-looking, televisual soap opera style, we might see stylistic elements such as blocking and set lighting as securing a cinematic reception in this case — one that also flows from cinematographic choices, not least the initial choice of a 35 mm film camera for production.

Do we really perceive the use of 35 mm film, however, from perusing this clip through YouTube? A certain richness and careful gradation of color and light may shine through what is admittedly a fairly compressed clip. While such an aspect of 35 mm film could be somewhat well-retained, there are other sides to a traditional, filmic aesthetic that is effectively destroyed by these conditions. Similarly, we might imagine the TV sets of the 1980s doing comparable work on the scene in it its original reception setting. The subtle quality of film *grain*, for instance — fluctuating particles of metallic silver, visibly inhabiting the analog film image — does not survive this level of digital compression and distortion. Film grain generally seems to only have begun to appear visible on television screens recently, with the combination of modern HD displays and very high-quality sources such as Blu-ray. Yet grain may be given much of the credit for film's attractive and peculiarly analog qualities — constituting an important part of its aesthetics. Grain, according to Stephen Prince (2004, p 31), "gives the celluloid image its special luminosity and vividness. The grain pattern is never the same from frame to frame, making each frame a unique visual experience." If we were to view this scene in a remastered Blu-ray version, the restless, "organic" texture of film grain would probably announce itself (provided it hadn't been digitally removed from the images). This would presumably heighten and complete a "film look" proper, for *Dynasty*.

In considering film grain, the usage of the term "texture", as evoked earlier, may seem intuitive: the grain appears as fluctuating markings covering the surface of the film image. Conversely, the texture of video may be that of no particular texture, a "clean" image, in this respect. Grainy texture is virtually lost in the actual *Dynasty* clip. Yet there remains, arguably, a "global", "covering" quality that seems to announce the clip's filmic origin — one that, by virtue of those characteristics, may also have a claim on the term "texture": Put shortly, the whole picture *moves* like film. Gaining this impression does not require a sample of the clip of any length at all. On the contrary, it can be almost immediately seen and "felt". The nuanced lighting, and the film camera's particular ability to record such nuance, is another factor that cannot be discounted in this immediate impression. Yet, I would contend that the issue of a

particular, ever-present appearance and sensation of *motion* may be successfully held apart from this (and other factors), and singled out for consideration on its own.

To open such a consideration, we may begin with the observation that traditional movie cameras are bound to a certain range of *exposure time* for each frame. More specifically, the mechanical, rotary shutter of an analog 35 mm camera needs to halt the access of light for a significant part of the time a given film frame is situated for exposure. This is because the shutter cannot be open (light should not intrude) during the process of progressing the roll of film (Iseli and Loertscher, 2016, p. 459). Exposure time determines resulting motion blur in the image, and affects the sensation of “smoothness” of film motion. Analog film cameras, because they record motion no faster than 24 fps, need to use the restricted amount of motion blur available to them in order to gain a smoothly moving picture that does not clearly “skip” — i.e. exhibits one of the kinds of motion artifacts considered in chapter one, "unsmooth motion". In practice, this has mostly come down to a configuration of the rotary shutter mechanism where it is set at 180°, which translates to being open to exposure for half of the time, or 1/48th of a second. This is where film cameras typically have their upper limit for exposure time (ibid.). In using a traditional 35 mm camera, then, *Dynasty* is highly likely to operate with the same motion-relevant parameters as any other production using the same equipment — feature films, prominently.

Other types of cameras, which do not have the same mechanical restrictions as 35 mm cameras, may in contrast be able to achieve the exposure of a frame for its *full* duration. This blurs the images on the frames *more*, further smoothening the transition between them. HFR formats can also make gaps between frames less apparent, through actually filling them with more frames — more isolated instances in time. Motion blur may constitute its own manner of "filling-in", as was considered with the notion of blur registering as information about depth movement, in chapter one. Though introducing motion blur is a different operation from recording more frames, a similar, overall effect of perceived motion "smoothness" may result.

I, Claudius

Compare *Dynasty's* filmic textural qualities to a brief scene, just under 30 minutes into the first episode of *I, Claudius, A Touch of Murder* (1976). Emperor Augustus (Brian Blessed) is here conversing with his wife Livia (Siân Phillips):

Fig 2.2. *I, Claudius,* episode one, *A Touch of Murder* (1976)

Continuing with the issue of the fundamental appearance or "character" of motion, the intended focus here is, very narrowly, on the shot the above still frame is taken from — looking for its immediate first impression. First of all, we find a “smoothened” sense of motion, compared to *Dynasty*. It is present here specifically, as well as globally, throughout the rest of the series. The smooth motion will necessarily be dependent on a certain configuration of exposure time and frame rate, as outlined above. Both variables may be important, yet hard to single out from each other, in the total yielding of the particular motion on display. Video cameras may vary considerably with regard to both of the variables. When it comes to exposure time, they are not beholden to the mechanisms which limit traditional film cameras, and may thus allow exposure for the full duration of every picture frame. As for frame rate, a British TV-camera setup is likely to correspond to the PAL (Phase Alternating Line) analog broadcasting standard, adopted throughout most of Europe, which uses a refresh rate of 50 hz: the image updating 50 times per second. Images are broadcasted in an "interlaced" manner, meaning that only half an image (half the horizontal scan lines on the TV) is sent and displayed every 50th second (Brinkmann, 1999, p. 163). Television cameras, conversely, may directly record in this format. The result, despite these particularities, is one of a smoothened appearance of motion, comparable to a doubling of the amount of regular, "full" frames (50 fps compared to 25 fps).

If we momentarily move beyond motion, and consider lighting and color, there is also a certain harshness or “drabness” to the pictures. This is visible from the above still frame, much as it is from the moving shot — and we may expect the videotape format to play a role in this. While *I, Claudius* may generally conform to a uniform "television"-style of lighting, this shot does not appear to exhibit it particularly strongly. Available nuances of light and shade are nonetheless likely to be less vividly captured than they would on 35 mm film. There are also, presumably, ways in which the trained eye will identify specific, subtle (or less subtle) visual artifacts, characteristic of the videotape medium. One feature here may be a perceivable "color bleeding effect", for instance, where certain colors seem to spread out from their correct locations and "bleed" into adjacent areas (GTH Electronics, 2009).

Despite these factors, when looking at the *still frame*, there appears to be nothing that emphatically suggests that this specific shot couldn’t be film. Especially not if we consider the possibility of film that had been degraded somehow, through some process of time and/or wear, distortion, or perhaps a transfer onto a videotape format like VHS. Set the scene in motion, however — *press play* — and merely the subtlest shifts of the actors’ positions, or a slight camera pan, as Brian Blessed steps toward the camera, carries a subtle but decisive sign that one is *not* in the domain of cinema. It seems reasonable to suggest that in this marked shift, and an absence of cinema, there is also a chime of the liveness-effect discussed above — and the televisual in general. It can be striking, in a sense, how effectively this is accomplished — and the particular sensation and “character” of movement appears to be of great importance here.

A special role for motion

Examining these two works of television, I am thus led to single out and further question this somewhat subtle issue of motion and its appearance — for the role it may play in forming viewer receptions of images as "cinematic", "televisual", "live", and so on. These different characteristics of motion may be more *sensed* than they are presenting themselves for precise verbal description or analysis, beyond terms such as “smoothness” or “fluidity". The degree to which a given viewer finds such characteristics of motion similar or dissimilar, generated through and across various technological conditions, may differ considerably. This includes sensitivity to any differences *at all*, also those between traditional film and HFR. Uniformity in this regard would be surprising, especially in light of a wide variation in responses to HFR and its purported "soap opera" effect — as explored by Michelle et al. (2015).

Provided a level of sensitivity, however, differences should very much be available for conscious discernment. Following the exploration above, I would like to highlight a certain *resilience* these motion characteristics seem to exhibit — resilience to attenuation, or obfuscation. Given a type of motion that is formative of a cinematic aesthetic, for instance, this stands in contrast to other “textural” qualities of film — ones that are prone to disappear entirely with decreases in image fidelity. Contrary to this, Roy Armes, in his book *On Video* (2006, p.194), writes that “the small screen domestic viewing situation renders the recording substance (film or tape) virtually indistinguishable to the general viewer”. While it hard to speak to how perceptive a general viewer may be, I will submit the notion that a distinctly “filmic”-looking image seems to survive onto a low-fidelity situation — such as compressed video, VHS, or an older television set. A potentially crucial factor in this could be how such compromised images still manage to exhibit a specific sense of movement. Film’s vivacious color, grain and other features may be virtually absent, but motion seems to remain demonstrative. This demonstration could perhaps best be described negatively, as a certain *lack* — lack of the smoothness of motion engendered through other media than film.

There may be a range of technical-scientific explanations that could shed light on how minutiae of motion comes to have such a resilience — matters of motion sensitivity in the human visual system, for instance, that go beyond the scope of the inquiry that I am able to make here. One possibility that is closer at hand can perhaps be found with a slight recourse to a signal processing perspective, and Andrew B. Watson's "window of visibility"-model (Watson, 2013), introduced in chapter one. While movies at 24 fps are generally considered acceptably smooth, the non-smoothness that can still be subtly perceived is a motion artifact, intruding upon the human window of visibility. As considered before, motion blur is a very significant means of attenuating the intrusion of temporal artifacts (Watson 2013, p. 20). *Spatial* blur, on the other hand — i.e. a general blurring of the entire picture, not specifically a blurring of motion — may not be nearly as effective at hiding those artifacts, because it does not affect the temporal part of the signal in the same way. (On the other hand, it may be highly effective at hiding *spatial* artifacts, such as the characteristic "jagged", "staircase"-like edges seen with computer graphics at low resolutions). Thus, while un-optimal technological conditions surrounding film presentation may introduce blurring or other obfuscations, under various circumstances, film motion's particular appearance (of relative non-smoothness) may have been left fairly unaltered — determined mostly by the particular amount of motion blur present from recording. This is in turn determined by frame rate and exposure time —

normally 24 fps and 1/48th second for film. These are two fairly constant parameters throughout the last 90 years of cinematic images (since the standardization of 24 fps), on account of the camera technology used — whether it captured shadowy abstractions or full-bodied, meticulously lighted Hollywood sets. Film's particular character of motion may thereby have remained demonstrative throughout a wide range of filmic expression, and also throughout various viewing situations where film has been received *outside* the cinema — be it TV broadcast, home video or compressed YouTube videos.

This could point us to certain characteristics of motion as an extraordinarily definitive feature of the "look" of various types of moving images. If motion occupies such a special role, this may help in understanding how audiences' understandings of what they are watching are so effectively pushed *away* from the "cinematic" — even in an overall aesthetic situation where everything else may remain distinctly cinematic. Such situations are to an extent what will explored for the rest of this chapter, as we turn to examining two professional works of HFR cinema: *Billy Lynn's Long Half-Time Walk*, and *The Hobbit: An Unexpected Journey*.

HFR cinema analyses:

Billy Lynn's Long Half-Time Walk

A significant stretch away from the fantasy-world of *The Hobbit*, Ang Lee's *Billy Lynn's Long Half-Time Walk* tells a somber story of a young, American soldier coming home after a tour of military service in Iraq. A key scene in the film is a "flashback" to a particular combat experience of the titular character, taking place from roughly 1 hour, 12 minutes and 50 seconds into the film. This scene is currently (as of May 2018) viewable on YouTube, in a true 60 fps — to be found through the reference list: The HDR Channel (2017).

"True" here is intended to discern between 24 fps film that has been "up-converted" to higher frame rates through various "motion interpolation" techniques, where a computer algorithmically determines what frames between actual recorded frames should look like, and inserts them into the flow of images (Shin et al., 2008, p. 1). Following an upgrade to 60 fps playback capability in 2014 (Welch, 2014), YouTube is home to a vast array of cinematic content that is merely interpolated into higher frame rates. We even find trailers and footage from the *Hobbit*-trilogy that is *up-converted from their 24 fps versions*, as if to provide a reconstruction of the HFR version that did not see release outside of theaters. The resulting

aesthetic, while bearing strong similarities to HFR's "smoothness" of motion, is not identical to it — no actual (i.e. authentic) image information, recorded during production, is gained. The YouTube-excerpt from *Billy Lynn's*, however, stems from the 60 fps Blu-ray release of the film — presenting 60 unique frames of recorded footage, per second of film.

Revealing the artifice

As an object of analysis, what *Billy Lynn's* may function especially well for is as a test case for some of the issues of an unwelcome "realism" circulating around *The Hobbit*. This is what we will now turn to. Foregrounded among these issues is the notion that the trilogy encountered problems with HFR's clearer image — revealing imperfections and artifice in the movie production. Complaints to this end have gone as far as pointing out what may be considered outright "gaffes" of filmmaking, brought to light by the higher clarity of the HFR picture. Given the otherworldly fantasy setting, actor Ian McKellen's contact lenses did not stand witnessing, yet some accounts would have it that these were made visible: "Those who have seen The Hobbit particularly complain that while spectacular landscapes look great, the fibreglass sets, rubber noses and even Gandalf's contact lenses are embarrassingly obvious." (Williams 2012). Insofar as this specifically is the case, it would constitute a somewhat clear-cut special case of cinematic *faux pas* — a violation of ideals for mise-en-scène, where the diegetic story-world should not show signs of its artificial production. As one moves from contact lenses to "fiberglass sets" and "rubber noses", however, things quickly become more diffuse. Discerning the appearance of fiberglass, as distinct from mythical alloys native to J.R.R. Tolkien's world, may quickly become an unstable exercise — one of knowing the appearance of the former, while speculating about the fictional appearance of the latter.

While *Billy Lynn's Long Half-Time Walk* wouldn't stand visible prosthetic noses any more than *The Hobbit*, its story-world is much more accommodating of contact lenses, and rely very little on material surfaces that are not (or far from) what they purport to be. Taking in the above clip from *Billy Lynn's*, mostly everything appears starkly "real", in a material sense. If not actual items of clothing made by the U.S. armed forces, combat uniforms have every appearance of being meticulous reproductions in the appropriate fabrics and materials. The gritty, smudged faces of the beleaguered soldiers, under the harsh daylight and the shadows of their helmets, admit no particular signs of make-up-work. The rifles they carry could be real weapons, if not replicas that differ only internally from their real counterparts. These examples extend to the overall dust-ridden desert setting, the material surface of which

appears beyond any layman's reproach for inauthenticity. Not only does such an impression seem to survive HFR's striking level of detail — the format also appears to play a role in *enabling* the scene to "revel" in the material richness and authenticity of its mise-en-scène. At around 01:13:10, we find a shot of Billy Lynn's squad taking cover while two rocket-propelled grenades decimate parts of their surroundings:

Fig. 2.3: Ang Lee's *Billy Lynn's Long Half-Time Walk* (2016)

Fig. 2.4: Ang Lee's *Billy Lynn's Long Half-Time Walk* (2016)

The vivid appearance of splintering stone and rich plumes of dust and smoke, enveloping the screen, is on-camera effects work (Dynamic Effects Canada, 2016) — real explosions. Visual

impressiveness aside, this could be received as a rather unremarkable instance of contemporary, effects-saturated Hollywood. With the entry of 60 fps HFR, however, it may be suggested that the shot has the potential to appear to us *rendered anew*, as fresh spectacle: The crystalline HFR recording luxuriates in the clouds of smoke and dust, conveying an abundance of information on their smooth unfolding. This information is likely to resonate with our tacit understanding of how such particles behave in the real world. Seen in light of what Stephen Prince (1996, p. 31) terms "perceptual realism" and a "correspondence-based model" of cinematic realism, HFR here affords us ever more information about an on-screen event — information which adheres to "structured correspondences between the audiovisual display and a viewer's extra-filmic visual and social experience." An expert in military armaments may hypothetically take issue with the general manner in which the explosions are portrayed. As a representation structured to target a range of visual experience familiar to the general viewer, however, the shot gains impact through a demonstrative sense of lush correspondence with the behavior of real-world materials (sand, smoke, dust).

This is a perspective on HFR that may stand in some opposition to the more skeptical views on HFR's connection to greater realism, as proponents of the technology are prone to espouse. Julie Turnock exemplifies this academically informed skepticism: "It is worth noting that more pixels per inch, additional inputted data, and faster rendering times provided by digital technology are simply new representations" (Turnock 2013, p. 44). In a "correspondence"-perspective, hopefully eschewing naïve conceptions of realism, such "additional inputted data" may be a means to refine and deepen the viewer's recognition of correspondences between real life-experience and what is portrayed on-screen.

The *quality* of HFR's abundance of data may be absolutely crucial in this regard, however. With the practical effects considered here, the new technology's piercing view appears to be used in such a way as to only open vistas onto further, convincing layers of real-world visual correspondence. This may thus support a notion that HFR does well under less "artificial" circumstances of filmmaking than was the case with *The Hobbit*. From this specific perspective, the technology may even be demonstrated to live up to high-flung claims for greater realism (although the concept of realism remains perpetually problematic in general).

Additionally, it should be considered that we find a *blend* of digital and practical effects in this shot, portraying similar phenomena. As can be discerned from a "behind the scenes"-video by the special effects company responsible (Dynamic Effects Canada, 2016), the rush of

smoke trailing the first projectile was not captured on camera, and must have been added digitally. It is visible in the air above the soldiers, in figure 2.3. Lingering in the air as it does, immediately before and during the cascade of real smoke and dust, we may see the HFR capture as placing an added pressure on the digital effect to stand in juxtaposition with its extremely vivid real-life counterpart — acting as a side-by-side reference point for real-world correspondence. While filmmaking craft appears to put this shot ahead of any clear "perceptible visual disjunction" between practical and digital effects, as Michelle et al. (2015, p. 13) refer to, the voluminous vividness of the on-camera effects could contribute to rendering this delicate co-existence more precarious.

At any rate, there is not much time to take in the difference, as the shot rushes by in a few seconds. If there is a slight threat of visual disjunction coming into play here, *more advanced* CGI should be a clear-cut path to erasing it. If there is a current impossibility of an HFR-shot identical to the actual one, where all effects are computer-generated, this seems only to depend on the evolving state of the art. All of this would conform to a picture that CGI, and other artifices of mise-en-scène, may fall more easily short of higher visual standards set by HFR — and that it happened to do so with the *Hobbit*-trilogy. It would also follow that better CGI, greater craft — a process of learning to work with the technology — shows promise as a way to improve future reception of films in HFR.

An uncanny climax

In contrast to the above, there is one other effect in the same combat scene from *Billy Lynn's*, remarkable in its own right, that appears to anomalously stand out as highly *artificial*. At 01:15:30, there is a shot of a faceless figure, engaged in combat with the U.S. troops, being quite literally torn apart by a .50 caliber machine gun:

Fig. 2.5: Ang Lee's *Billy Lynn's Long Half-Time Walk* (2016)

Even if one connects the figure's violent disintegration to the heavy, vehicle mounted weaponry seen in a follow-up shot, this appears very excessive — unrealistically so. Yet, the stark sense of visual transformation of the picture, through 60 fps, may be a cue prompting skepticism toward this very reaction: Has the higher framerate exposed some horror of modern warfare, which actually has a fair claim on being a factually sound depiction? Viewing the scene in the 24 fps version of the film, the oddness seems to persist, albeit slightly more diffusely. The body of the figure virtually *disappears*, from head to feet, in a red mist. This is tied in with a previous scene in the movie, where Billy Lynn explains to a civilian what a .50 caliber machine gun does to a man: "If you hit someone with a .50, it takes them apart like… Like a pink mist." Regardless of the scenario's relation to real-life physics, it is interesting to consider the idea that its HFR presentation might lend salience to a questioning of such categories as "reality" and "fakery". John Belton, in one of his treatments of HFR cinema, suggests that the technology has the capacity to evoke the psychological "uncanny" and unfamiliar, Freud's *unheimlich* (2017, p. 402). If we entertain such a notion, this particular shot in this scene has to be seen as a climax of such uncanniness. (Meanwhile, the scene's *dramatic* climax only arrives some moments later). Through being thrown off a familiar viewing position and visual engagement with "cinema" as we know it — sensing the intrusion of a "live" psychology of the image — we may be less bound up in a familiar, complacent mode of receiving the on-screen action: was the short moment in question

surreally horrific, in some stark, immediate realism, or merely "fake"? Subsequent rewinds and pauses might suggest the latter conclusion, while perhaps also missing the point: Given the audacity of the effect on display, and the filmmaker(s) behind it, this could be a very deliberate, artistic play with audiences' current relation to cinema and HFR. Hovering between unfamiliarity to cinema, familiarity to other genres and heightened correspondences (and familiarities) to aspects of lived, visual experience, the scene may indeed be *intended* to evoke discomfort and psychological ambivalence about the status of the images and its depictions. It could be seen as fitting, then, to have this ambivalence punctuated by a conceptually unstable moment of violent *death* — death, and uncertainty over life and death, being a key facet of the uncanny. Emerging from the movie darkness, we might question what was seen in that short moment, and if it even seemed "real" — as a traumatized soldier might question the subsequent reality of the most horrific things he saw in war. This would certainly be a very specific and sophisticated employment of HFR, to serve artistic ends. Its embrace of the unfamiliar and uncomfortable, while possibly effective, does not seem to suggest promise for more traditional Hollywood forays into heightening the *pleasure*-aspect of visiting the dark, communal space of the movie theater.

Props on a set, props in a game

Parallel to, and flowing from the above explorations, there is another key remark to be made on this scene from *Billy Lynn's*. While almost all of its visual aspects exhibit a highly convincing surface materiality, the psychological ambivalence of the images seems to simultaneously threaten to recast the entirety of the scene as "*fake*". In attempting to account for this, it should first be emphasized that the "psychology" of the image, in this scene, can appear to draw very strongly in the direction of a liveness-effect. Following J.G. Butler, we may ask whether stylistic features, besides the smooth, video-like motion texture of HFR, work to enhance this. Soap opera seems intriguingly displaced, however, *far* displaced, even, as a salient category with which to apprehend these images. While a lack of cinematographic hallmarks of soap opera may contribute to disenabling the scene's conceptual pinning onto this frame of reference, it also seems that *another* genre could be seen as strongly (and quite diabolically) intruding to take hold of interpretative efforts — toward a particular frame in which to apprehend a liveness of the image: the *live sports broadcast.*

Sports TV was initially alluded to, in the introduction, as one out of many contenders for various genres evoked by HFR cinema. Why sports TV, for this scene in particular? Some suggestions, for how various stylistic aspects could contribute to this, are:

- HFR's particularly intense motion clarity, at 60 full frames per second. While the exact frame rate is not likely to be of consequence here, it may be noted that 60 fps has been the high-definition broadcasting standard for leading American sports cable company ESPN (Browne, 2014).
- The stark, outdoors daylight setting, bathing the scene in a uniform, natural sunlight.
- The virtual lack of variance in depth of focus: everything, foreground to background, is rendered in sharp detail.

What remains as a tie to soap opera in this conceptual pull, then, is maybe only a very isolated sense of "character" of motion, as highlighted earlier. To put it one way, not in *movements*, made by the camera and actors, but in *movement* itself: the felt impression of how edges of objects transition across different parts of the picture frame, or how visual information transitions *into* the edges of the frame, as the camera moves.

If we posit sports broadcast to be the dominant association here, in lieu of soap opera, even further (disturbing) connections could perhaps be traced — such as one between sports and the physical, martial exhortations of soldiers in war. While there is nothing faulty with the construction of the film set, it nonetheless comes in contact with a conceptual reframing as a faked, artificial "arena" for war — like a visage of a dystopian, modern revival of the Roman gladiatorial games, complete with 60 fps live broadcast. There thus seems to be an overall conceptual dissonance at play here, mediated by a liveness-effect, that gives rise to this sense of artificiality — a seemingly live, highly produced view onto actual, bloodied warfare does not have a sound place to conceptually "settle". This notion, I would contend, also reflects on the idea of a similar view onto another, entirely implausible situation for live mediation: J.R.R. Tolkien's Middle-Earth. While there may be some merit to the idea of HFR putting pressure on mise-en-scène to be executed in a (perceptually) realistic manner — as was explored with the smoke effects above — it seems that there could be a much deeper issue at play in why audiences apprehended *The Hobbit* as "fake". *Billy Lynn's* appears to demonstrate this for us, through extracting HFR from the fantasy artifice of *The Hobbit.* Fiberglass swords may not at all seem fake on account of being a poor substitute for metal swords. Rather, it may be suggested that swords look very much like "props" on a set, just as actors look like

actors on a set, under the sheer conceptual purview of a "live" apprehension of the images.

HFR cinema analyses:

The Hobbit: An Unexpected Journey

While the most uniquely intriguing aspects of *Billy Lynn's Half-Time Walk* may have turned the discussion away from a deeper consideration of HFR and the soap opera, the first *Hobbit*-film offers a very good opportunity to place this front and center. (Yet not without the possible intrusion of yet another contending "genre", of a kind, as we shall see).

Consider again the hallmarks of soap opera style, expounded on earlier in the chapter: A languid, intimate and “elegiac” (Timberg 1983, p. 76) manner of cinematography is not initially expected to be what brings an action-spectacle like *The Hobbit* into contact with the soap. Numerous parts of the trilogy, such as the chaotic chase through the goblin caverns toward the end of *An Unexpected Journey* (2012), would seem to bear out this expectation especially strongly. The scene in question begins in earnest at around 2 hours and 26 minutes into the movie, and depicts the wizard Gandalf (Ian McKellen) and an entourage of dwarves running and fighting their way through an elaborate cave system filled with malevolent goblins. It lasts for about four minutes, ending with Gandalf's slaying of their leader, the "Great Goblin".

For those audiences who tied a “soap opera” label to *An Unexpected Journey*, we have no way of knowing how salient this label remained to them throughout the film — throughout the film's various constituent parts and sequences. Would it be as prevalent, if the *entire* film operated on the intense level of the caverns sequence? While some modern Hollywood films may aspire to a near ceaseless flow of action scenes, this is not the case with *An Unexpected Journey*. There is J.R.R. Tolkien's classic children's story to be told, ripe with relatively calmer moments of character interaction, dialogue and exposition. Key among these is the roughly 20 minutes long introductory scene in the home of main character Bilbo (Martin Freeman), taking place about 20 minutes into the movie. Here, he is accosted by Gandalf and a company of dwarves, on which he will embark on the titular unexpected journey with. We may use this as a scene to contrast and compare with the caverns chase scene toward the end of the movie.

The caverns chase scene

In assessing the caverns chase scene stylistically, we would likely have to place it on the far reaches of modern Hollywood style labeled “intensified continuity” by David Bordwell (2002, p. 16). That is to say, particularly far away from the classical “invisible” Hollywood style — perhaps nearly as far as one can go, without breaking the basic tenets that style rests upon, such as the preservation of spatial coherence through the 180-degree-rule. Cutting throughout the sequence in question is very rapid, and a soaring, swooping camera is at times given free reins through computerized caverns. At the same time, spatial coherence is well preserved, organizing and tempering the action.

Fig 2.6: The “goblin caverns chase” from Peter Jackson's *The Hobbit: An Unexpected Journey* (2012)

We may here have to make a similar observation to the one made with *Billy Lynn's*, above: in this particular scene in *An Unexpected Journey*, there could hardly be a more crystalline departure from the soap opera — in virtually every aspect — in a film conceivable within the Hollywood paradigm:

- Dialogue is absent or negligible — no traditional "shot/reverse shot"-constructions are there to support dialogue.

- An extreme cinematographic dynamism: The camera (or virtual camera) is constantly on the move, continually engaged in an assortment of virtuoso maneuvers, working in

concert with the athletic maneuvers of the lead characters.

- The scene takes place in a vast outdoors expanse of nature, whose grandness is frequently presented in long shots — juxtaposing diminutive lead characters against the epic, threatening scale of their surroundings.

- The scene is extremely intricately lit, in a nuanced, "painterly" style — likely owing its result to the entire filmmaking process: from concept illustrations to digital post-production.

If we posit "soap opera" to still remain a salient label to a given viewer, within this specific scene, it may point us to considering it in fairly reductive terms: It may be operant on the level of a simple analogy or heuristic, a reference point that effectively captures the base sensation of motion associated with HFR — all while being interchangeable with evocations of other genres, displaying similar motion characteristics. From this view, it makes *practical*, pragmatic sense to apply “soap opera” as an explanatory term across the entirety of *An Unexpected Journey*. The 48 fps format aesthetically covers and affects every shot and second of the film — every instance of motion — quite regardless of all other stylistic variables or types of scenes involved.

This may indeed be as far or as deep as a "soap opera" comparison can be taken to go. On the other hand, we might be led in a different direction, by way of the comments on *The Hobbit* made by John Belton, mentioned in the beginning of the chapter: “For me, the look of The Hobbit can best be described as that of a *soap opera on steroids*” (2014, p. 8, emphasis added). The statement, in context, is mostly a brief offering of personal impression. If we are to consider the exact wording here with some serious interest, however, some fruitful ideas may emerge. It can be interesting to entertain the idea of some scenes in *An Unexpected Journey* as an actual “*soap opera on steroids*” — placing them on an extended spectrum of "cinematic" versus "televisual" soap, as was suggested earlier. Belton's wording appears suggestive of something that is an overflowing and forceful exaggeration of, but still *fundamentally* a soap opera. Here, we might discern how certain parts of *An Unexpected Journey* comply better with such a picture than other parts. The expository introduction scene in Bilbo’s hobbit-abode — which we will now turn to — may be seen to operate *relatively* closer to the stylistic foundations of classical Hollywood, compared to the caverns chase scene. Thus, we may perhaps also expect it to operate relatively closer to soap opera — while

also keeping in mind aforementioned qualifications to this comparison made earlier, between soap and Hollywood style. What follows is an examination of how this scene may bear out such a picture — or stand in contradiction to it.

The introductory meeting scene

To say that classical style is easier to trace in the introductory meeting scene, compared to the caverns scene, is not to say that we here find an exemplar of "invisible" style. The logic of “intensified continuity” appears to remain operative, on an attenuated level — occasionally stretching the potential for a dynamic style to assert itself, within the parameters of a dialogue-centric interior scene. A fairly static shot-reverse-shot form is employed to accommodate some scenarios, such as in the very beginning, when Bilbo answers the door to the first few of the twelve dwarves that invade his home:

Figs. 2.7 and 2.8: From Peter Jackson's *The Hobbit: An Unexpected Journey* (2012)

As he suspiciously tries to make sense of his unexpected visitors, they trade lines across the doorstep, framed in tightly controlled, 3/4, medium-length shots. As intensity in the scene goes up, with Bilbo losing all semblance of control of his surroundings, more dynamic *long takes* become prominent. The camera tracks and pans between various sections of the hobbit home to capture the action, abstaining (for some time) from cutting. Together with these longer takes are quick, montage-like cuts to various aspects of the ensemble cast causing a ruckus — throwing plates, food, scavenging the hobbit's food supply, etc. Jackson seems to hold off on the means of dynamic style and cinematic intensification, until the narrative motivation is in place for them.

Visual intensity decreases again, as the leader of the dwarves, Thorin Oakenshield (Richard Armitage), arrives at around 28 minutes into the film. The cast gathers around a cramped table for more intent (and more important) dialogue, where mid-to-close-shots take precedence — covering various configurations of the 14 characters present. Shots are calm in terms of camera movement, but not always entirely static, even if actors are. The camera may subtly pan across or track across/against characters for added dramatic effect, congruent with what Bordwell (2002, p. 20) terms "the free-ranging camera", a trait of intensified continuity. Dramatic flow does perhaps play a slight role in these subtle mobilizations of the camera, but not overtly so. Jackson appears to opt for employing it in a fairly uniform manner, even as the music swells to meet some dramatically salient moment — such as Gandalf revealing the key to the secret passage into The Lonely Mountain. While some talking points may be tenser than others, the characters mostly remain seated around a table, talking. This basic premise appears to keep the camera quite discreet, at least in this scene, to Jackson's directorial sensibilities.

Fig. 2.9: From Peter Jackson's *The Hobbit: An Unexpected Journey* (2012)

Furthermore, a more distanced mid-shot shows up recurrently, one that may be sufficiently withdrawn to barely constitute a master shot of the scene:

Fig. 2.10: From Peter Jackson's *The Hobbit: An Unexpected Journey* (2012)

Despite the amount of characters being a potential complicating factor, the scene largely works from a traditional template of cutting between this "master shot" and reverse angles of actors addressing each other, alternatively opting to show the talker or the listener's responses to what is being said. At times, both speech and reaction is combined in a mid-shot comparable to the "two-shot", except for there often being more than two characters' faces comfortably visible at a time. Whereas Bilbo is moving in and out of the room, in the background, all other characters stay in the same position. The camera may move, between cuts, to oppose the set angle of the "master shot". This enables proper frontal views of all the dwarves, at different appropriate times. Great care is meanwhile taken to keep characters that are interacting in a set left-right relationship, defined by the 180-degree-lines between them.

Other modern Hollywood directors than Peter Jackson would perhaps find it proximate to their style to take the premise of the whole scene in question, and force a more dynamic approach — delving more into a modern, intensified paradigm, eschewing the traits of transparent classical style and its striving to "efface" the picture plane (Bordwell et al., 1985, p. 50). As it stands, Jackson's specific solution appears to turn most variables at his disposition toward the distinctly cinematic — although within some conservative limits of the type of narrative scenarios that are in question, and the modern Hollywood paradigm he is bound to. A more demonstrative, dynamic style plays an important part, but is constrained to narrative elements of the scene that motivates such exhortations. Meanwhile, conventions of

classical style — which may have a necessary degree of overlap with the intimately framed "talking heads" of television or soap opera — intercede to effectively convey dialogue, and thus effectively tell the story.

Unsettling close-ups

Despite not being *overtly* or uniquely televisual, the conventional elements of filmmaking outlined above may have worked in conjunction with HFR's "smooth" texture of motion, in order to pin a widely reported "soap opera"- or "television"-reception onto *The Hobbit*. Soap opera *does* seem a more proximate category in this scene, it may be suggested, compared to scenes looked at previously. This may stem from greater similarities to the soap, on one hand — on the other, there may be a less salient associative register of *other* genres for the images to settle in. In such a case, this may serve as an additional useful demonstration of the psychological gravity that HFR's altered sense of motion can bring with it: Traditional tools of filmmaking and cinematography being recast in the light of soap opera and television — despite them being entirely naturalized to cinema in their own right, and the overall context being strongly geared toward the cinematic.

Potentially resonating with this are certain public statements by Douglas Trumbull, where he evokes the niche genre of the kinetic *ride* simulation film as an example of a context where HFR is naturalized. Cinematic close-ups, on the other hand might encounter problems: “A lot of [James Cameron's 2009 film] Avatar is kind of like a ride, so that's perfectly appropriate for high frame rates, but I see how a close up of Gollum might seem weird or uncomfortable.” (Brandom, 2013). The meaning of "weird or uncomfortable" here may, based on other statements, be locatable close to the issue of a "live" psychology embedded in the images — a trouble that Trumbull reportedly pioneered encountering with his 60 fps analog Showscan format. Working on a period drama about Leonardo da Vinci, Trumbull noted that:

> it looked really weird, because it had exactly what people are reporting about The Hobbit, of a texture that is too much like a live television drama. So the distinction in my mind is one of: what’s the appropriate kind of movie to apply high frame-rates to — and what’s not?
>
> (Labrecque, 2012)

In *Gollum*, Trumbull speaks of a close-up of a completely *computer-generated* character, which activates the issue of CGI being "unveiled" as "fake", not "realistic" enough. While this may have some merit, there is also the alternative perspective presented above — that various visages on film may seem "fake" for running squarely into a cognitive dissonance with HFR's "live" psychology of the image. Yet further, in the singling-out of Gollum in a *close-up*, there is the possibility of an effect such as the one under current consideration: elements of style, shared by both film and television, securing such a liveness-effect (as well as related receptions of genre). Thus, while Gollum is used here, troubles with character close-ups and HFR do not necessarily seem to be confined to CGI or otherwise fantastical (or historical) characters. In evoking both the niche simulation ride film, a filmic expression stripped of traits of conventional cinema, and asking the question "what is the appropriate kind of movie to apply high frame rates to — and what's not?", Trumbull may be taken to suggest that mainstream cinema must depart rather drastically from traditional forms to escape the psychological dissonances that are courted with HFR. Avoiding visible fakery or "fantasy" may not be sufficient. On the contrary, "fantasy" or "history" may then have no particular lack of affinity with HFR, provided that a movie is "the appropriate kind of movie", stylistically.

It remains as a looming question, however, what it takes for a movie to sufficiently achieve such appropriateness. It bears mentioning here that Trumbull had an early, formative filmmaking experience working as a special effects artist on Stanley Kubrick's iconic *2001: A Space Odyssey*. In large parts stripped of dialogue, and thus the formal elements typically accompanying dialogue, *2001* may still be seen as waypoint for a uniquely cinematic language — one that radically eschews the stylistic tendencies of Hollywood classicism. One of the most famous of Trumbull's effects contributions to *2001* is the psychedelic "star gate"-section toward the end of the movie:

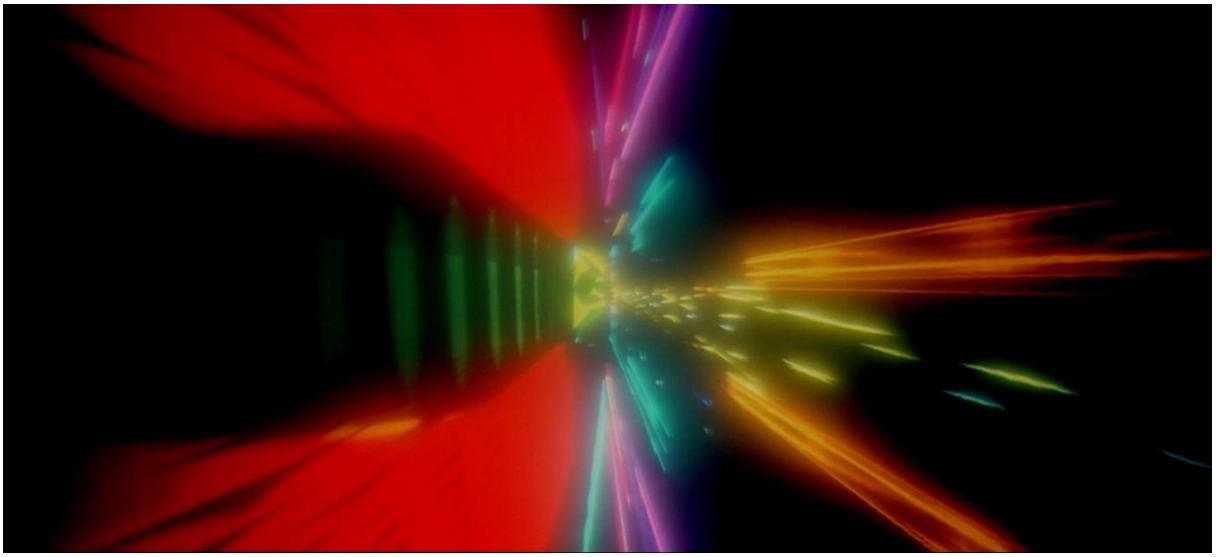

Fig 2.11: "Star gate" section from Stanley Kubrick's *2001: A Space Odyssey* (1968)

Here, as the film makes an avant-garde turn away from all figurative form, we can most likely expect to securely locate a context where HFR's particular "gap-less" sensations of motion — had they been present — would be far removed from the issues of "liveness" that have been explored in this chapter till now. To this, we may pose the question: is a fantasy-sci-fi-film such as James Cameron's *Avatar* (2009), and its projected sequels — cited by Trumbull in his statements above — sufficiently *different* to escape the pull of these effects?

Variable Frame Rate (VFR)

Cameron is expected to utilize HFR technology in the upcoming *Avatar* films. While being a vocal proponent of HFR, the director appears to recently have expressed doubts at its wholesale applicability in a cinema context:

> "In terms of that kind of hyper clarity, there may be some films that benefit from it," he continued. "But I feel you still have to have a little bit of that *veil of unreality* that comes with [today's commonly used] 24 frames per second. This is my conclusion now. I don't think you do it wall-to-wall, I think you do it where you need it.
>
> (Giardina 2016, emphasis added, comments in original)

As with Trumbull, Cameron's media statements necessitate some interpretative work to engage with them. (Given that these are two of the most profiled professionals actively working with HFR currently, the work should be quite warranted). Using HFR "where you

need it", as Cameron puts it, is indeed an emerging option with the opportunities afforded by digital technology. This tends to be called "Variable Frame Rate" (VFR). Frame rate may not just seamlessly change from one shot to the next, but also within *one and the same shot.* If the source material is shot in 120 fps, for instance, every fourth frame may be selectively removed from *some* part of the picture (but not others), to effectively yield 24 fps in those parts. As shown by the work of Krzysztof Templin et al. (2016, p. 1), it may even be technologically feasible to freely change the amount of frames-per-second to numbers that are *not* divisors of the refresh rate of the cinema projector (complicating operations such as simply removing every *n*-th frame). This opens up to a range of interesting scenarios. The filmmaker may choose to increase frame rate only *marginally* up from 24 fps, to 28, for instance, to soften a slight "judder" effect. This may be done only in the background, or to some moving object, keeping other elements, such as actors, at a strict 24 fps. In doing this, a *de facto* "24 fps"-look may be meticulously preserved throughout a movie — with higher frame rates only making a slight incursion to remedy issues of viewing comfort. Indeed, this seems to the chief concern of Cameron, as he in the same interview states that:

> "I think [high frame rates] is a tool, not a format. I think it's something you want to weave in and out and use it when it soothes the eye, especially in 3D during panning, movements that [create] artifacts that I find very bothersome. I want to get rid of that stuff, and you can do it through high frame rates.
>
> (Giardina 2016, comments in original)

In contrast to this, we may imagine a simpler, yet variable use of HFR, where different categories of scenes are subject to different frame rates — differences perhaps also being quite demonstrative, so as to properly benefit from an abundance of extra image information and clarity. 24 fps and the *Hobbit*-trilogy's 48 fps may be one such set of co-existing frame-rates. Despite future *Avatar*-movies possibly fulfilling Trumbull's idea of the franchise being "kind of like a ride [film]", it does not seem unlikely that they will also find themselves beholden to the telling of a "classical", character-driven narrative — not too unlike *An Unexpected Journey*. While a spectacle-driven, revived "cinema of attraction" (Gunning, 1986) may be a track that Hollywood is fast settling into in the 21st century, the total displacement of more conventional scenes does not seem imminent. It thus presents itself as a possible strategy to let action-spectacle scenes operate in one broad register of HFR, where motion perceivably takes on an altered character, while less "intense" scenes stay in a lower,

traditional frame rate. What may frustrate such a strategy, however, is the liveness-effect that HFR seems capable of endowing the film with. If prone to perceiving an "ontological" shift in the felt time of the unfolding images, will viewers readily accept scenes in different framerates within one and the same movie — one and the same diegesis? Important here, then, could be the possible ability of film style to divest the images of the "liveness"-quality associated with HFR, through being explicitly "non-televisual". More fundamentally still, however, the mere presence of two distinct "sensations" and "aesthetics" of motion — within one and the same film — may become jarring to audiences. At any rate, a strategy such as this remains completely untried with the public. While unclear, there seems to be at least a possibility (from his statements) that James Cameron has encountered some disillusionment with the idea of a truly "HFR" cinematic experience, even in selective parts of a movie — now seeing it rather more as a "tool" to subtly "weave in and out of" (in his words above) what amounts to a consistent, fairly traditional "look" of film.

HFR and video games

To round off this chapter's consideration of *An Unexpected Journey*, and the broader issues it activates, we may make a brief return to the chase scene in the goblin caverns. Prompted by the circumstances of Cameron's Avatar-film(s), and Douglas Trumbull's references to the "ride" film, there is a remaining, pertinent observation to be made about this scene. First of all, owing to the characteristics listed earlier, it seems reasonable to assume that the scene lies close to what Trumbull is pointing to as HFR-appropriate filmmaking: spectacular, fast-moving action, contained in dynamic, "epic" sweeps of cinematography. Indeed, it may seem much like a rollercoaster-experience, like a "ride". But what came much more forcefully to my own mind, viewing the film in HFR 3D, is a vastly more prevalent, even dominant part of today's media landscape: the *video game*.

There is something distinctly video game-like about the frantic chase through the caverns. This extends to similar, CGI-enabled action sequences subsequently experienced in the rest of the trilogy (in HFR). Video games run at varying frame rates, but typically they are minimally targeting 30 fps, and 60 fps is seen as an ideal standard to be sought after (Andreev, 2010, p. 1). Some configurations of video games, then, to varying degrees, will enable a “smooth” character of motion. The goblin chase sequence exhibits much imagery that unavoidably has a computer-generated quality, regardless of its highly sophisticated photorealism. The fantastic subject matter also recalls the fantasy worlds of many video games. At one point, around the 2

hours and 27 minutes-mark, we are even treated to a brief first-person perspective of the wizard Gandalf cleaving through goblins on his way through the cave system. When we see his wizard staff swinging at his enemies, in a first-person view, the video game analogy becomes extremely tangible: first-person views in various video games are typically accompanied by a weapon or tool of choice, visibly extending out in front of the player's viewpoint. Also, the left-to-right "scrolling" character of another shot, where Gandalf and the dwarves are running in line after a rolling rock (02:28:50) may also evoke video games operating in the "classic" two-dimensional configuration — with the player character overcoming obstacles as it runs left to right. (Also, while this moves us from visual style to more narrative concerns, it may be worth mentioning that the scene ends with Gandalf fighting and slaying the chief goblin (02:29:30). Tthis character is larger, more dangerous and more hideous than the common goblin, much like the video game trope of the climactic "boss battle").

What all of this could labor very effectively to do, then, is to force HFR's sensations of motion onto a wholly different path of association than that of soap opera — effectively displacing it, well out of consciousness, by a demonstrative video-game-"look". This may again suggest how avoiding a televisual apprehension of images may not just be a case of avoiding stylistic similarities to television — but also actively seeking out other conceptual schema for the images to resonate with. Eliciting an impression of a non-interactive “video game on steroids” may be an effect that the modern action-fantasy-filmmaker welcomes, and which is viable to aim for, given video games' cultural prominence. This could point us to a larger, on-going cultural process in which conventional "live-TV"-associations with higher frame rates may be eroding, perhaps to the point of rendering many of the issues in this chapter moot. At the same time, 24 fps remains very strong in the realm of audiovisual, "cinematic" entertainment — extending beyond movies to the contemporary paradigm of "quality TV" television serials, for instance. Some caution may be warranted, in assuming that familiarity with a video game-aesthetic means that younger audiences want their video game worlds to flow into the world of cinema.

Conclusion

This chapter endeavored to explore a set of key phenomena that heavily contributed to the interest in writing this thesis: those of HFR film appearing more "realistic" and immediate, as if "live", to audiences — as well as being evocative of genre and media that diverge widely

from cinema. Examining specific, relevant works, for the particular effects that they may elicit, there appears to emerge a fairly convincing picture of HFR's "motion texture" as only one of many stylistic factors subsumed in a larger, interpretative field — the sum of which has an important bearing on the saliency of a liveness-effect, a "soap opera"-effect or even a "video game"-effect.

The particular role of HFR's "filling-in", of the perceivable the gaps in the film image, is not to be underestimated, however. In its own subtle way, those gaps may be such an inherent, psychologically salient part of what constitutes cinema that their removal is particularly effective in throwing the images into an unstable conceptual state. This may be very accommodating space for other conceptual framings move in, to settle this interpretative discord — especially if there are other visual factors which contribute to HFR resonating in a "live television" schema, for instance. The effect of this subversion — simultaneously tearing images *away* from cinema and convincingly moving *towards* the televisual — may be so effective that it is very hard to avoid, even with the best efforts to make "film" and not "television".

Within this apprehension of liveness, we may not know what to do, in a sense, with certain features of what we see on-screen. Gandalf's ancient, mythical sword has no place to settle conceptually, regardless of how perfectly realized the prop is — and neither may a dusty site of desert combat in Iraq have this, intriguingly. This notion provides a significant challenge to any wholesale assertion that HFR seemed "fake" to audiences, on account of revealing technical weaknesses in the *Hobbit*-trilogy's rendering of mise-en-scène — whether in practical, on-set materials or in digital post-production.

While possibly very potent, this smooth-motion effect of HFR would not seem to be boundaryless in its ability to steer our sensations to television and an associated liveness — as if transgressing any reasonable similarity to other visual aspects of these genres. *The Hobbit* may at times be so evocative of the video game, and so eschewing of anything remotely resembling television, that it achieves the same effect — but perhaps not without the threat of television, or even soap opera, re-entering conceptual purview at the slightest opportunity. As of today, HFR may thus be faced with a formidable task of escaping its current associative register — but not without a significant potential for successfully embracing certain parts of it above others, which may be seen as more attractive. A "video game look" may displace a "soap opera look" and/or a "live TV look" in HFR blockbusters of the future. Video games

may have their own sets of ties, however, with the ordinary, "cheap", "not-special-enough", "not-cinematic-enough", also for young audiences that are steeped in them. On the other hand, an assumption that young audiences are not only widely accustomed to higher frame rates in general, but also widely accommodating of them in all contexts, could show itself to be well warranted in the long run. This suggests one possible, particular way for a spectacle-driven HFR-cinema to eventually overcome the obstacles faced by *The Hobbit*.

CHAPTER THREE: Frame rate beyond convention

Introduction

The third chapter of this thesis will endeavor to investigate the possibilities for identifying more *inherent* features of the aesthetic reception of various frame rates — and the possible significance of any such features, as this pertains to film-watching and filmmaking. By "more inherent", the intention is here to discern between the effects of *learned* cinematic *conventions* — particularly the arbitrary, contingent association of 24 fps with the cinematic, or 50 and 60 fps with the televisual — and possible aspects, of the reception frame rate, that go beyond such a conditioning-effect.

Whereas the perspectives onto frame rate and conventions that were explored in chapter two may on their own provide a highly fleshed-out picture of the issues faced by HFR cinema, it is also striking how entrenched 24 fps appears to be, throughout these. Ambivalences such as those signaled James Cameron, cited earlier, contribute a certain impetus to the idea of going further than the perspective that has been employed up till now. To recapitulate:

> In terms of that kind of hyper clarity, there may be some films that benefit from it," he continued. "But I feel you still have to have a little bit of that *veil of unreality* that comes with [today's commonly used] 24 frames per second. This is my conclusion now. I don't think you do it wall-to-wall, I think you do it where you need it.
>
> (Giardina, 2016, emphasis added, comments in original)

The conclusion to the previous chapter was by no means a consignation to the indefinite future relevance of 24 fps — particularly not for blockbuster "spectacle"-type-cinema. Yet this seems to be what Cameron draws toward in this statement, despite being one of the foremost proponents of a techno-progressive attitude of a "bigger, brighter, better" cinema experience — in which 24 fps may well be posited as an antiquated anachronism (particularly as it stands alongside ever higher spatial resolutions, laser projection, etc.). Cameron's wording here — the "*veil of unreality*" of 24 fps — could be taken to suggest an apparent effectiveness of the traditional frame rate, to heighten the experience of moving images into a particular, affective register that is enjoyed when watching film — "the cinematic". (Which

may or may not be connected with the images' divergence from "reality", in some sense). This may have a full explanation in a relatively uncomplicated conditioning effect — one where viewers are taken to have been exposed to 24 fps in innumerable films, therefore (and virtually *only* therefore) appreciating 24 fps for a particular affect and "enchantment" that is received as appropriate for film. (The absence of which may have left some viewers of *The Hobbit* in HFR "disenchanted", in the formulation of Michelle et al. (2015, p. 4)). Could there be other, significant factors, however — as of yet unaccounted for — contributing to frame rates' effect to this end?

Chapter question and structure

What emerges as a rather singular, driving research question for chapter three, in light of the above, can be formulated as follows:

- Can there be identified any aspects, of cinema's traditional 24 fps frame rate, that could contribute to an account of that frame rate's perceived appropriateness and effectiveness for cinema — running beyond a simple conditioning to 24 fps as the "film look"? How may these be described, in that case?

This question opens up to what is potentially a very wide field of inquiry, and research was begun through a correspondingly wide investigation. Eventually, parts of this investigation oriented itself toward *cognitive* science and sciences of the brain. These fields appears to hold particular promise in eliciting concrete and interesting findings, from a topic that may be slightly opaque in nature, as will be examined.

Moreover, there is one particular perspective on frame rate, incorporating cognitive science, which is central to the majority of chapter three: I will examine the significance of the minute spaces found *in-between* the updating of images in film — where there is a very small period of projecting a single still image, pending the transition into the next one. These spaces, and their potential differences in size, are a fundamental way to conceive of how various frame rates differ from each other. There is considerable interest attached to the question of how this may affect how film motion — and thus the motion picture more generally — is processed and perceived. The fruitfulness of the investigation into this topic, with regard to the chapter question, has warranted its foregrounding in this chapter.

One instigating source of inspiration, in this regard, is a somewhat famous "mantra" of Canadian animator Norman McLaren. It seemingly bore a great deal of importance to McLaren's view of his own work — to the point that it was observed written on a sign attached to the animation equipment in his offices. The sign read as follows:

> THE PHILOSOPHY BEHIND THIS MACHINE: Animation is not the art of DRAWINGS-that-move but the art of MOVEMENTS-that-are-drawn. What happens between each frame is much more important than what exists *on* each frame. Animation is therefore the art of manipulating the invisible interstices that lie between the frames.
>
> (Small and Levinson, 1989, p. 68, line breaks edited for convenience)

McLaren here suggests the idea of a crucial role of the spectator, in giving "life" to the animation, by inferring and "creating" (for themselves) the implicit movements in those "invisible interstices" between drawings. Film here appears as a special case of animation, for all practical purposes — and frame rates of 24, 48 or 16 fps (etc.) provide different lengths of interstices, both spatially and temporally. The notion of a significant, mental process of "filling in" between frames, dependent on frame rate, has driven research from a very early stage in the work on this thesis.

The investigation that pertains to the perspective above will take place in two parts: The *first* part will take some examples of the "chronophotography" works of Étienne-Jules Marey, Georges Demeny and Eadweard Muybridge as objects of study — so as to attempt to gain a preliminary, productive entry, into the spaces in-between each frame of film projection. These spaces rush by very fast, even in 24 fps — whereas in chronophotography we may (arguably) see them as being arrested for our perusal. Alongside this, I will also explore film motion at *very slow framerates* (significantly below 24 fps) — the experience of which appears to have some points in common with chronophotography. These aesthetic situations will be taken as points of departure, to investigate whether they can be fruitfully connected to the experience of watching 24 fps film — particularly by way of the *unconscious*. The perspective on the unconscious that is utilized here is chiefly that of cognitive psychology and neuroscience — but its discussion also contains a brief, psychoanalytically oriented contribution from film theorist Laura Mulvey.

The *second* part, of the investigation into the interstices between images, will foreground the spatial aspect of these — the fact that a lower frame rate means that individual frames "skip", from one to the next, a greater distance than they would with a higher one. There are possibly some very interesting insights to be garnered here from the current state of science on the brain, and the workings of the human visual system — particularly in the distinction between a "long-range" system and a "short-range" system for motion perception, as described by Axel Larsen, et al. (2006) and Oliver Braddick (1980)**,** among others.

Relinquishing the focus on the interstices between images, for the final section of the chapter, I will consider possible significances of 24 fps representing *less information in the image*, compared to HFR — and the idea of a fundamental affinity between traditional cinema and a "*less is more*"-approach to film aesthetics. In part, this will be an endeavor to inscribe high and standard frame rates into a traditional formalist perspective on film theory, as exemplified by theorists such as Rudolf Arnheim. As we shall see, this could potentially provide a fairly clear rationale for why inherent attributes of 24 fps is beneficial to cinema as we know it. Alongside the topics outlined above, this perspective has thereby distinguished itself, in its apparent significance for the questions posed in this chapter.

Previous work

There has, to the best of my knowledge, been very little former work on frame rate that has tried to chart a course of inquiry that is similar to what is suggested through the chapter question, above. A study by Iseli and Loertscher (2016) situates some points of contact, to the subject of HFR, that appear relevant in this regard: This multi-faceted study attempted, among other things, to experimentally determine whether HFR (in a cinematic context) had an influence on the use of viewer attention. Eye-tracking technology was used to this end. A key connection here, to this chapter, is the resulting question of whether higher frame rates diffuse viewers' attention more — and whether this owes to a "novelty" effect of the HFR format in cinema (i.e. more a result of conditioning), or to more fundamental facets of how the visual system regulates attention, for instance. Altogether, however: the singling-out of the cinematic frame rate of 24 fps — for a theoretic discussion of its aesthetic and perceptual particulars, especially as compared to higher frame rates — appears to be surprisingly novel ground to tread.

Spaces in-between: 24 fps, chronophotography and the still frame

An invaluable tool, for some of the inquiries that follow below, has been the ability of modern technology to not only *stop* a motion picture at any given time — but also to carefully move between individual frames of the film, one at a time. Engaged in the exercise of looking between successive images of a moving filmic object, in this manner, one may have the experience that a particular aesthetic effect emerges if the images are depicting sufficiently *different* instances in time. A decisive tap of the finger can make the object "jump" to a clearly different position, compared to its previous one — and back again, and so forth. The experience suggested here appears to be of a kind with the particular, visual delights of some of the famous "chronophotography" works of Étienne-Jules Marey and Eadweard Muybridge — where views of various subjects, captured in the midst of their natural motion, are juxtaposed:

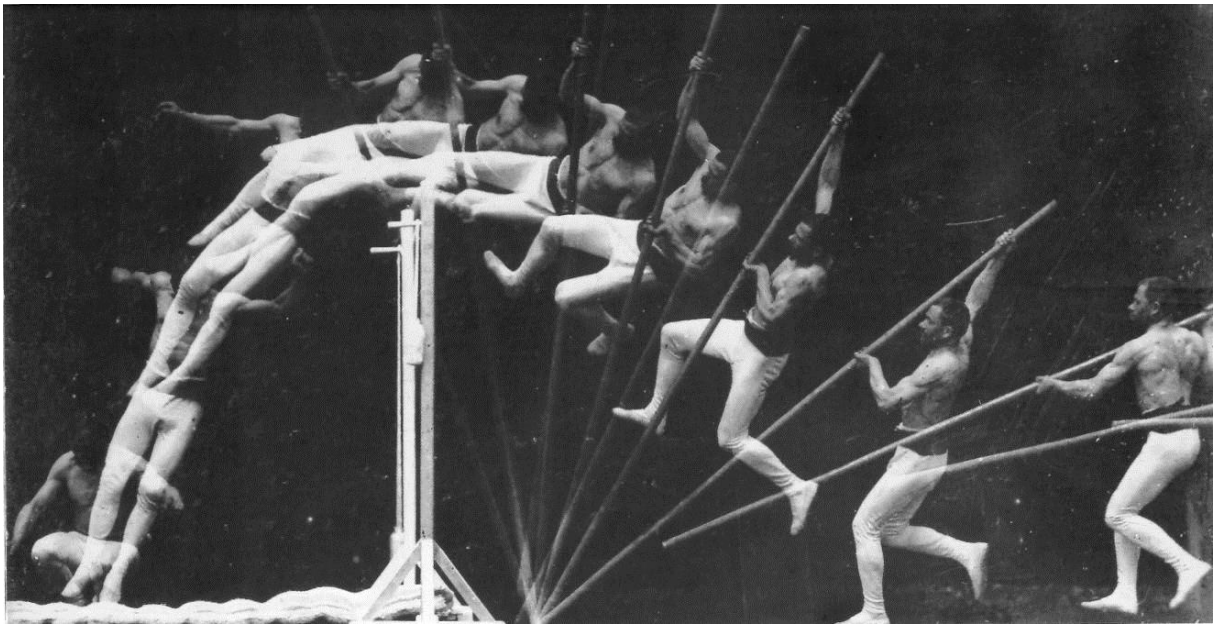

Fig 3.1: Étienne-Jules Marey*: Study of a man pole-vaulting* (1890)

Shifting our eyes from the chronologically second picture to the third, we may strongly intuit, *feel*, the forceful movement taking place — of the pole vaulter leaving the ground and lunging into the air. (Similarly with the subsequent steps of his journey over the bar). It is as if movement enters as a visual thought, transpiring on the cusp of the concrete perception that is the actual series of still images. This appears to be, in part, what philosopher Erin Manning

points to as the particular experience of sensing the movement expressed by Marey's chronophotography — and also *participating* in its perceptual actualization:

> These images do not represent movement, they move- with the movement of the feeling taking form. They are affective because to see is to feel-with, to participate in the intensive passage from the virtual to actualization. What is amodally felt, perceived-with, is the microperceptual appearing at the threshold of sight, but not actually seen.
>
> (Manning, 2009, p. 95)

Marey himself wanted to eliminate the considerable temporal gaps seen with the picture, so that no parts of the movement evaded the rigorous, scientific gaze he sought to bring onto it. This was frustrated by the overlapping of images, becoming chaotic if too many of them were superimposed simultaneously (Doane 2002, p. 49). The sense of participation that Manning alludes to, however — and the intensity of felt, "microperceptual" appearings — seem all the more salient in the substantial gaps that are here offered for their generation. While effective in their own right, the techniques that Marey devised to refine temporal granularity (while preserving legibility) seem that they could yield a somewhat different effect. Consider this dramatic representation of a fencer, made by Marey's assistant Georges Demeny in 1906 (a few years after Marey's death):

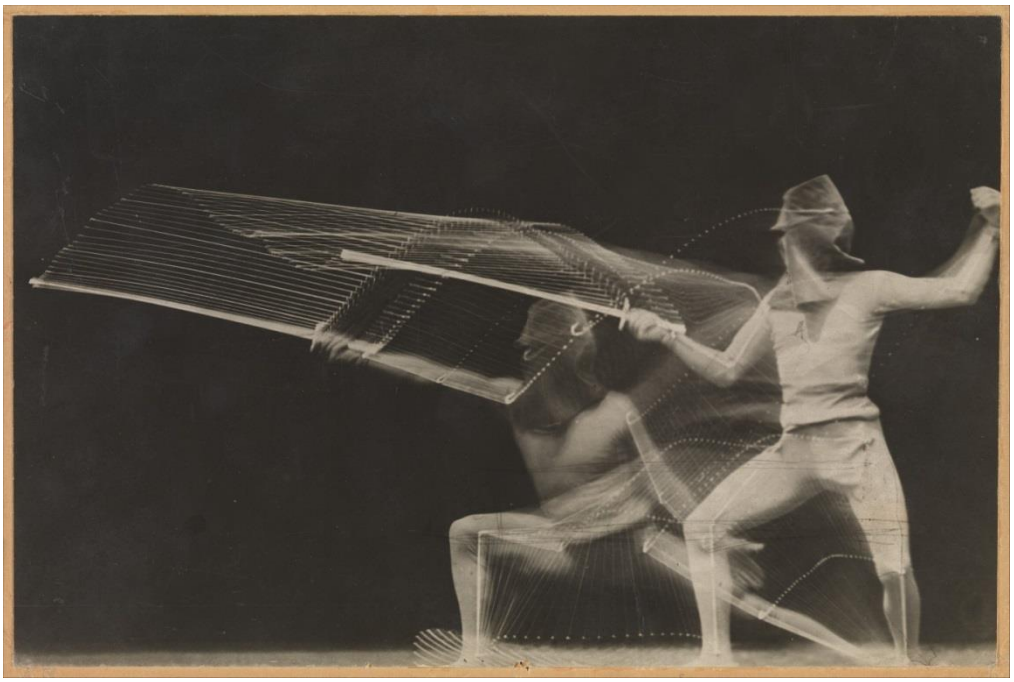

Fig. 3.2: Georges Demeny, *Fencer* (1906)

There are two clearer imprints of the fencer, at the beginning and the end of his thrust, which roughly correspond to the kind of interval in time that is expressed by the lunging pole vaulter. In-between, however, are illuminated stripes and points which carefully register the spatial-temporal passage between these two states — this was a technical solution of Marey's and Demeny's, to the problem of solid bodies being visually disorienting when many images piled up close together (ibid., p. 54). While the exacting view onto the fencer astounds with its force of demonstration, it may be suggested that it does not quite delight, in the same way as the pole-vaulter, with a wholesale *pleasure of participation* — of a *filling-in* that lingers on the threshold of perception, erupting from a bare *incipiency* of movement, contained in the sparsity of images. There seems to be a particular enjoyment, or at least a particular effect to be found in that virtual space, where *creativity* in movement-interpretation is completely foregrounded: now an entity is there, and now it is all the way over there, and one can *feel* and almost *see* (but not quite) the event in-between — an actualized movement.

Perusing Marey's static, yet "moving" presentations in this way, at our leisure, could be conceived of as an experience sharing a considerable affinity with movement in films with *very slow frame rates* — as slow as two, three or four frames per second, for instance. This easily allows for the seeing of a "slideshow" of individual still images — yet *movement* between them can nonetheless seem quite strikingly well-realized. Consider the sight of a series of lights sequentially moving, in a straight line, or perhaps "snaking" across the lamps of an amusement park installation. This is a primitive kind of film, in a sense. Even at a rate of only a few changes per second, the impression of *one* moving stripe of light keeps insisting — even as it is also perfectly clear that this is a static light array, which is simply changing states. At these slow rates of visual change, and in the static tableau of the pole vaulter, it is also clear that there is a process of *mental impletion* that has to be the source of a more-or-less realized apprehension of motion. And, to be sure, science has long had it established that the successful seeing of motion, on ordinary film, is also a mental phenomenon: filmic motion does *not* stem from a superimposition of successive views on the retina, a "piling-up" of images, as the remarkably widespread "persistence of vision"-theory posits (Anderson and Anderson., p. 3). Rather, what allows the still images to convincingly move, in so called "apparent motion" (ibid.), is a more cerebral, interpretative operation of the brain — a higher-level mental process. This was already established by the influential motion experiments by Max Wertheimer in 1912 (ibid. p. 6). What we may thus attain, then, is some preliminary cause to view ordinary, 24 fps film motion *in light of* the evidently "cerebral" movement of

ultra-low frame rates and Marey's chronophotography. (The latter could perhaps be seen to offer a *particularly* intimate encounter with a more conscious view onto a mental process of "filling-in", as we can seemingly linger in-between and back-and-forth between individual images — similar to the frame-stepping possibilities of digital technology). In the following pages, I will consider how 24 fps — a fairly "slow" frame rate, in a brave new world of HFR — can be seen in relation to these other, slower (or even *static*) expressions of apparent motion. How far can we go in (or how short do we fall of) tying these different phenomena together?

Sequential versus "fused" motion

While motion on 24 fps film is established to depend on the brain's interpretation of motion, it hardly affords us a chance to consciously grasp a conceptual "leap" — to "feel" the virtual movement emerging out of the relation between two photograms. Neither is a flow of film, at this rate, perceived as succession of still images anymore. In his experiments, Max Wertheimer found that two alternately flashing stimuli (two lines, horizontally separated) tended to be viewed as *one object*, moving back and forth, when their alternation became rapid enough. He termed this the "Beta phenomenon", which resembles real movement (real-world movement) (Steinman et al. 2000, p. 2257), and is the chief motion phenomenon experienced with cinema.

Wertheimer determined the optimal conditions for beta movement to occur when stimuli were flashed at a switching speed of about 60 milliseconds: faster than this, and simultaneity of the two stimuli would begin to take hold. Slower, and the stimuli would begin to be viewed as two separate ones flashed in sequence — rather than a single stimuli moving back and forth (Ibid., p. 2259).

If we take the full 1000 milliseconds contained in a second, and divide them by whole numbers corresponding to various frame rates, we get values such as:

1000/17 = 58.82352.. ms

1000/16 = 62.5 ms

1000/24 = 41.66666.. ms

There appears to be no general rule, for exactly at which frame rate an individual viewer is going to lose sight of the still images and "fuse" them, into one moving image. 16 or 17 frames per second seem to be in reasonable proximity to this, however. Meanwhile, convincing apparent motion on film can be very saliently present at a frame rate of 10 or 12 fps — seeing as how it can even be so at the very extreme low end, as considered above. It appears to be somewhat uncertain whether these sub-60-ms speeds should be included in what is termed the "beta phenomenon" — and also what significance should be placed in that threshold between "sequential" and "fused" motion: Is this a threshold between clearly differentiated, perceptual domains, as far as the viewer is concerned — does the brain engage differently with the images, on either side of it? There is at least a clear need to also speak of apparent *motion* at these lower frame rates. Beta movement may alternatively be referred to as "optimal apparent movement" (Steinman et al., 2000, p. 2257), which seems an apt resolution: apparent movement attains an "optimal" quality when still images are no longer apparent — but images are definitely "apparently moving" before this point, which is important to specify.

Slipping still images

We may from here consider the idea of a gradual move, upward in speed — from the starting point of chronophotography's "movement-in-stillness", and the very slowest of frame rates. The ultimate "target" here, in a sense, would be the full 24 fps of cinema. In the midst we have at least one milestone to consider, that of "fused" motion.

Somewhat prior to losing sight of still images, we may lose track of the ability to fully *appreciate* each frame, and the succession from one to the next, in the manner that has been suggested above. Granted, "fully appreciating", or perhaps "studiously taking in" still images, are diffuse notions — millisecond-values are definitely not applicable here. Yet, observing and moving between extremely slow frame rates and somewhat faster ones, such categories appear to hold some merit. The still images begin in a very strong perceptual grasp — the very strongest when they juxtaposed, as opposed to actually playing in sequence — and only *gradually* slip from that grasp, as frame rate increases. This may be exemplified through Eadweard Muybridge's famous 16-image horse-series — seemingly a popular candidate for latter-day animation of works of chronophotography:

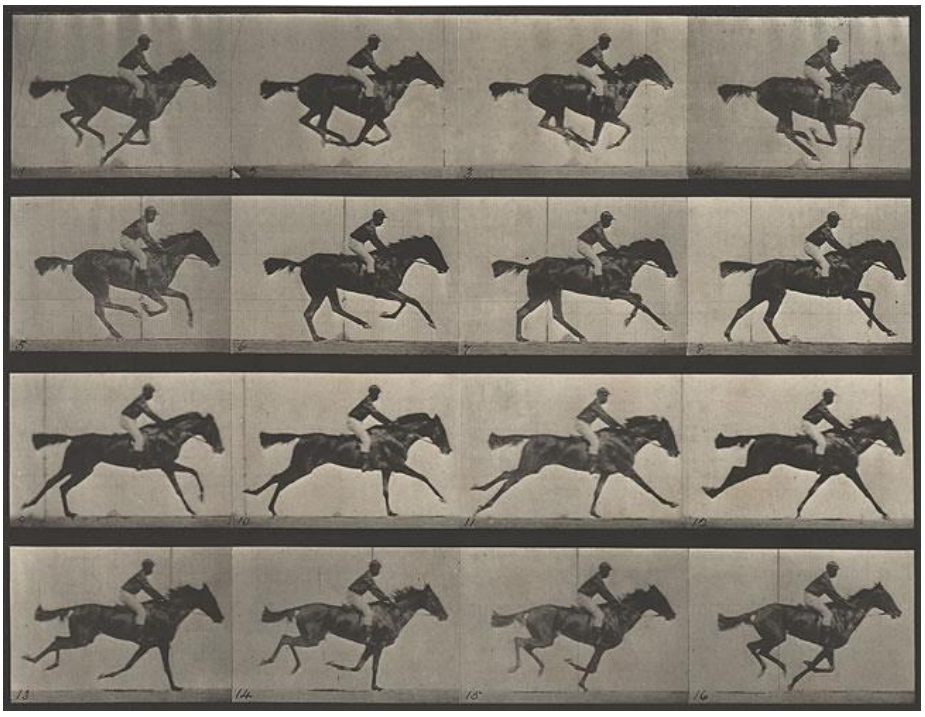

Fig. 3.3: *Human and Animal Locomotion, plate 626: Thoroughbred bay mare "Annie G." galloping*. Eadweard Muybridge (1887)

I have here used an animation of these images, provided through Wikimedia Commons (Waugsberg, 2006). With the speed chosen by the creator of this animation, following the frame counts in the lower left frame, the frame rate appears to be about 12 fps (or perhaps marginally higher than this). The horse and rider have here begun to attain a rather convincing flow of movement, where any one isolated still frame may be quite challenging to "arrest", in the mind's eye: to clearly appreciate, that is, exactly how one still frame appears before it is supplanted by the view of the next. At the same time, the particular stills seem to subtly pervade the moving scene — glimpsed and sensed. While there is very little time (no more than about 1/12th of a second) to take in, contrast and compare frames succeeding each other., it may be offered as a suggestion that *something* of that mode of studious comparing-and-contrasting — to be experienced from Muybridge's original tableau — resides in the forward flow: an appreciation of the isolated points of difference in position, and the perceptual implications in-between them. In that case, it appears to verge quite close to the subliminal — as if we have taken an experience once quite conscious, at lower frame rates, and shifted it toward the margins of consciousness.

If motion pictures had operated in the horse animation's proximity of 12 fps, then — as cartoon animation regularly does (Hawkins, 1989, p. 8) — there may have been a salient

opportunity to draw a more specific tie, between the pleasures of movie watching and the pleasures of chronophotography. Regular film is quite a bit faster, however. To continue from here, we may have to let the domain of *unconscious* brain processing pique our interest. Following from the idea that the perception of still images can seem to begin verging *on* a point of near-subliminality, as frame rates are slowly increased, it seems pertinent to ask whether some variant or remnant of this apprehension can continue *into* the subliminal — the domain of the (more-or-less) unconscious. The unconscious is somewhat inscrutable, by definition, and its entertaining immediately courts a degree of speculation. It may well warrant some attention, however — particularly in light of scientific data on just how fast the human unconscious works with images. This will be explored in brief below, before an overall emergent picture of 24 fps is discussed.

Unconscious speeds

Studies on subliminal imagery point to a fairly impressive ability of the brain, to discriminate between stimuli lying well beyond the conscious threshold. Masked, subliminal images of fearful human faces, considered a primal instigator of emotional response, have been shown to produce different responses than neutral faces — concentrated in the brain's amygdala — at a stimulus interval of 16.7 milliseconds (Williams et al., 2006, p. 652). This approximately corresponds to 1/60th of a second — or the transition of a single frame, in a 60 fps film.

Also, explicitly tying their work to the topic HFR film, Alon Zivony and Dominique Lamy (2015, p. 19-20) made a recent, solidifying confirmation of some pertinent facets of a visual illusion known as the "on-time"-effect. This is an illusion where a discretely moving stimulus is perceived to move faster if it is held at its successive locations for shorter amounts of time (ibid., p. 11) This corresponds to the differences between a standard film frame rate and HFR, where individual frames are held on screen for different lengths of time. Zivony and Lamy points this out, bringing up viewer reports of *The Hobbit* appearing to move unnaturally fast in HFR (ibid.) — despite actual time of displacement (across the screen) being identical with the 24 fps version.

What seems to be most pertinent to us here, is the fact that the illusion exists, the question of *why* it exists, as well as the assertion that it *does not* happen outside of *apparent* motion. It is not found with "veridical" motion, equivalent of that found in the real world, as asserted by the study (ibid., p. 11). Yet is found to be a robust and likely generalizable phenomenon

(ibid., p. 13) — also encompassing what may be considered very rapid conditions of apparent motion, such as those attained by the 48 fps version of *The Hobbit.* (Performing a millisecond-calculation for 48 fps, as done with other frame rates earlier, we get 1000/48 = 20.83 ms). One explanation suggested, for the illusion, is the following:

"Likewise, the on-time effect can be expressed as resulting from a weighted average of the speeds associated with a static (no-motion) signal and a motion signal. Accordingly, the on-time effect should be strongly influenced by the time window during which the static signal is accumulated."

(ibid, p. 20)

Provided that *The Hobbit* exhibited *the* "on-time" illusion, the mere possibility of this explanation (among other ones) would indicate that there is a significantly differentiated, unconscious "accumulation" of the 20.83 ms on-time interval of 48 fps HFR, and the 41.67 ms interval of 24 fps. (the latter possibly including some very brief intervals of darkness, as mentioned in chapter one — page 26). Even over this range of frame rates, extending beyond 24 and into what may be deemed as very fast (and spatially coherent), there is the indication that the mind does not seem to have interpretively acquiesced to merely seeing motion "as such" — i.e. "as real", as it is encountered outside of movies. To speak of "accumulation" here, of the "on-times" of individual frames, could only be to refer to unconscious processes. With a certain sense of a conscious "taking-in", of each distinct frame, beginning to slip already at 12 fps, we can definitely not hope to do this with speeds going *upwards* of 24 fps. Zivony and Lamy's study suggests, however, that the mind can still know differences at these levels, and perceptually sample frames accordingly. This could be seen as fairly remarkable — given that it from the outset would seem quite plausible that the medium has entirely "overridden" the human visual apparatus under these circumstances.

Unconscious seeing, subliminal haunting

The pertinent question that this trickles down to, for this thesis, is one of the conscious and unconscious perceptual happenings at that cinematic, historically privileged point: 24 fps. In light of the data considered immediately above, it can almost seem as if the visual system has generous time to absorb 24 fps, and even some capability to spare, in the reception of yet faster frame rates. 24 fps "shoots" by us, however, in typical experience — solidifying the pertinence of the long-standing theoretic question of whether filmic motion is to be

considered "real" or "illusory" motion. On the other hand, 24 fps *can* also seem "sluggish", to the attentive eye. Steven Spielberg's *Saving Private Ryan* (1998) has been briefly mentioned earlier, for the intriguing demonstration it gives of 24 fps *without* the traditional, moderate "gloss" of motion blur. The absence of blur may expose the 24 fps frame rate as residing in somewhat precarious territory — not quite sufficient, by itself, for a tolerably smooth motion perception. (Seeing the film's "staccato" effect throughout every film would likely become unpleasant). At the same time, to conceive of said effect as "seeing each frame" — consciously *grasping* each frame, only on-screen for 1/24th of a second — would not seem to be entirely plausible. This already begins to become a trouble with the animation of Muybridge's horse, treated above. Meanwhile, there is also that intriguing threshold stage that the horse animation seems to tread upon — where the viewer may begin to rely more on an "intuiting", as opposed to a pinpointing, of the photographs embedded in the flow. Together with cognitive science's indications for the acute, unconscious sensitivities of the human visual system, this may lend some impetus to a question of whether separate still images are in some sense still *sensed* in *Saving Private Ryan's* staccato flow of images. Regular film, holding the images reasonably sharp, and adding only a moderate blur — would not seem too far beyond such a notion, either.

While it proves hard to break these ideas out of a more suggestive and speculative realm, the notion of still images subliminally protruding from, or "haunting" the flow of motion that is comprised of them, is an arresting one. The still image is a particular mode of visual expression, with its own affect: the still photograph may be associated with a *pastness*, an effect of "present absence" or "presence that is now past" — as flows from Roland Barthes (1981) and was folded into the perspective on the "liveness" of moving images in chapter two (Butler, 1986, p. 58). The notion that cinematic images may also have this pastness-effect, along with photographic stills, might be productively tied to the idea that the single, frozen image is not entirely lost to 24 fps film.

Also, Laura Mulvey (2006, p. 12) devotes much interest to what she calls the "central paradox of cinema": "the co-presence of movement and stillness, continuity and discontinuity". Spurred by the emergence of the kinds of digital technologies that have been of much help to this thesis, Mulvey refers to their evocation of the "ghostly presence of the individual celluloid frame" (ibid. p. 26), which has been foregrounded in avant-garde cinema but also existed "more covertly in the great range of fiction film" (ibid. p. 8). What is being entertained in my discussion here, then, is the notion that this covertness was perhaps not quite "perfect",

as well as the possibility of a sensed, perhaps "ghostly" presence, imbuing 24 fps film with a diffuse but effective psychological salience — possibly stemming from a dialectic between movement and subliminal intuitions of stillness. This, in turn, could be contingent on 24 fps being situated in a territory of perceptual "thresholds", whereas higher frame rates may offer a more unambiguous perception.

No cause for particularly strong assertions is found here, however — even if the entry into frame rates and "in-between spaces", taken here, fruitfully activates these ideas and issues. (Hopefully this is inviting of future, productive discussion, and perhaps also research). As for how this entry can contribute to a fleshing-out of a general, preliminary idea of "mental impletion" or "filling-in" between still images, it may again be conceded that assertions are few, and not especially strong. A pleasure of participation in a mental "filling-in" *may* well be operant, when watching 24 fps film — but this essentially lies very close to the starting point of the investigation. The particular pleasures of chronophotography (etc.), in this regard, can relate to some residual, subliminal effect in 24 fps — but these phenomena are hard to tie together, particularly beyond the point where images start fusing entirely together with one another. (In the proximity of 16 or 17 fps, assuming that Wertheimer's beta-phenomenon captures this threshold). Demeny's fencer (fig. 3.2), however — with its extremely acute registrations of movements from one positon to another — may have some bearing on HFR and its perceptual effects. High frame rates, as well as excessive motion blur, may leave an analogous impression of motion information "everywhere" throughout an actor's sword thrust — whether sharply arrested or smeared, respectively. A moderately blurred 24 fps, however, as is the cinematic standard, could have a better chance of producing still frames where the moving body (and various parts) appear as *one*, blurred but somewhat contained entity: moving from "here" to "there" to "there", so to speak, when looking on the individual frames — comparable to Marey's pole-vaulter. Insofar as the visual system has an unconscious grasp on the particular appearances of these still frames, this may be important. This also relates quite strongly to the *next* approach that I will take onto this somewhat opaque subject, of frame rates and the "gaps" they leave in film — to follow in the section immediately below.

Spaces in-between: Short- and long-range motion perception

In the previous part of the chapter, the concepts of beta movement and (optimal/non-optimal) apparent movement were invoked. Current understanding of the human visual system delineates between at least two categories of motion perception, which may further divide apparent motion into two distinct categories. These appear quite interesting for us to consider here.

The categories are termed short range motion and long range motion — hence also short- and long-range *apparent* motion. (For the sake of brevity, "apparent motion" may here be shortened "A.M."). Which kind of apparent motion that is found in film becomes an interesting and potentially important question, to pose and also to scrutinize — the reasons for which will be treated below. First, a description and delineation of the short- and the long-range systems:

"There is psychological and neurobiological evidence of at least two distinct systems for analysis of visual motion in man (Zhuo et al., 2003; Larsen, Farrell, et al.,1983; Anstis, 1980; Braddick, 1980): a short-range system that analyzes small spatial displacements (0.25° or below) across the retina, and a long-range system that captures large displacements. The short-range system may be based on banks of low-level motion energy filters (Adelson & Bergen, 1985), which are bypassed by the long-range system."

(Larsen et al. 2006. p. 1174)

In addition to very small spatial displacements, the short-range system depends on rather small temporal intervals as well: 100 ms or less (Larsen et al. 1983 p. 11). Going above these narrow temporal and spatial limits, a more accommodating long-range system takes over. The long-range process tolerates spatial displacements of many degrees and long intervals of up to 300 ms (ibid., p. 12). Important to us here is the distinction between significantly different neural systems and pathways, for arriving at similar (but not necessarily identical) impressions of apparent movement: "Outside the limited domain of the short-range process, apparent movement should be signaled by a higher-level, long-range process." (ibid., p. 11). Furthermore, "a higher-level" process would be a "central" as opposed to a "peripheral" one in the brain's visual system, and the short range-system is considered more "peripheral" (ibid., p.

16). A lower-level, or more peripheral process of motion-detection, distinguishes itself in being less "interpretative" than a high-level one — the latter being what is elicited by displays used in classical motion experiments (Braddick, 1980, p. 137), such as those of Wertheimer. The short-range process thus corresponds to a more "automatic" mechanism where motion is less inferred, through a higher level of processing, but picked up directly by more fundamental excitations of the visual apparatus in the brain — possibly "banks of low-level motion energy filters" (Larsen et al. 2006. p. 1174).

Owing to the smallest spatio-temporal displacements possible, real motion — the motion of objects moving continuously in the real world — belongs to the domain the short-range system. As for long-range motion in the real world, Yan Zhuo et al. (2003, p. 417, p. 420), in their fMRI study of brains experiencing such motion, assert that it is a commonplace occurrence. When a running animal disappears behind an object and reappears shortly after, we take it to be one and the same "object" that has moved some distance, during the interval in which it was gone from sight — even as it might be very differently shaped from one view to the other: legs curved versus legs outstretched, etc. (There are presumably possibilities suggested here, for how an evolutionary perspective may account for the development of a separate long-range motion system in the brain). This equation occurs following the brain's solving of the "correspondence problem" (ibid.), where different stimuli in two successive views are processed and interpreted to be matching views of the same object (Zhuo et al. 2003, p. 417). Larsen et al. explicitly refers to a perceptual "filling-in" by the brain — of "more or less sketchy mental representations of stimulus objects in successive positions along the computed motion trajectory" — taking place between such successive views.

Moreover, Zhuo et al. (ibid., p. 417) further specifies how the brain may be operating differently — or at a higher, "interpretative" level — with long-range motion: Findings from fMRI suggested that the brain's *visual ventral pathway*, associated with form perception, became more involved when study participants were subjected to stimuli corresponding to long-range A.M. Also, this neural response was modulated by deliberately induced differences in the visual shape of the stimuli, as it "moved" (disappeared and reappeared further ahead) on the display. This resonates with a propensity to see differently shaped stimuli as being the same object "morphing" from one shape to another (i.e. a square morphing into a circle) — a phenomenon induced by long-range A.M.: "However, when one views long-range AM between two forms, and these forms have dissimilar shapes, one perceives not only translation and rotation but also plastic deformations of the shapes." (ibid.).

With long-range A.M., then, scientific accounts seem to significantly bear out a general notion of interpretative impletion, in the "mind's eye", of perceived movement — and thereby also an altered perception of movement, depending on the conditions inherent to this part of the visual system.

Traditional movement on film

From the picture outlined above, it emerges as a rather interesting question where motion on film is situated, with regard to the categories of "short range" and "long range" motion perception. Film theorists Joseph and Barbara Anderson move, in very short order, to assert that the motion on film is *short-range* apparent motion:

> Motion in the motion picture is, as we have said, an illusion, but since it falls within the short-range or "fine-grain" category, it is transformed by the rules of that system — that is, the rules for transforming real, continuous movement. The human visual system can (and does) distinguish between long-range and short-range apparent motion, but it seemingly cannot distinguish between short-range apparent motion and real motion. To the visual system, the motion in a motion picture is real motion.
>
> (Anderson and Anderson, 1993, p. 10)

Indeed, motion falling under either of these two categories fall under the rules of that system (i.e. that visual system of the brain) — which may be significant, on account of differences between those respective "rule-sets" for processing motion. Anderson and Anderson here suggest the bringing of short-range A.M. to bear on the question of whether filmic movement is an "illusory" phenomenon or not. In relation to this, interestingly, their conclusions are also briefly directed towards Jean Louis Baudry's theory of the film apparatus — where it is considered to be rendered moot, on account of the visual system being essentially unconcerned with the "discontinuity inscribed by the camera" (i.e., the spaces between the frames of a motion picture)" (ibid. p. 11). Baudry, then, sees the film camera as serving a kind of lie or illusion through its discontinuous capture of images. While his theory is not the interesting matter to us here, in itself, Anderson and Anderson's dismissal of it — *through* their dismissal of the discontinuity between images in film — is potentially troubling. It is perhaps also troubling even *before* considering whether they are entirely correct in ascribing film's movement to short range A.M., which will be treated further below.

Viewing 24 fps cinema, it seems a contentious notion that there should *no* "discontinuity" that applies to the moving image — or, at the very least, no potential for it to reveal itself under right conditions. One such condition would be relative screen size: When watching film on a screen encompassing most of the visual field, as is perhaps seen as an optimal viewing situation, moving objects will make bigger skips, from the position in one frame to the next. As touched upon in chapter one, these skips may become quite apparent with 24 fps — and potentially a challenge to viewing comfort — especially with higher object speeds on screen.

Giving Anderson and Anderson's argument its fair due, their more specific contention would presumably be that what discontinuity there is *doesn't matter:* the spatial-temporal gaps of 24 fps are small enough so as to pass within the scope of short-range A.M. — the images thus being processed by the brain as if real-world smooth motion. It seems problematic to make this conflation, however, without due diligence in recognizing that the apparent motion of 24 fps bears a distinct and perceivable *lack* of the kind of perfectly seamless, smooth motion inhabiting the real world. Certainly, cognitive science appears to be on solid footing, in its delineation of the two different neural processes for motion perception that have been brought up here. Simply equating 24 fps cinema with real motion, however, seems to be an unfortunate move — foreclosing the possibility of any important nuances or novel details that transcend the binary significances of either "short-range" or "long-range" apparent motion.

Moreover, the question of which of these two important categories that film motion falls in does not appear to be quite settled. As mentioned, the boundaries between short- and long-range A.M. distinctly depend on both the parameters of *spatial distance* and *temporal offset* between stimuli. Depending on exactly what stimuli a film presents us with, it does not seem inconceivable for both short- and long range A.M. to occur within the same flow of images — side by side, or in seamless succession. A special case, such as a slow-framerate cartoon "embedded" in a live action film (a shot of a cartoon running on a TV screen, for instance) would presumably yield long range A.M, easily. We might not have to deal in exceptional cases like this, however.

Reviewing the necessary conditions for short range A.M., mentioned earlier, Larsen et al. (2006, p. 1174) puts spatial displacement at lower than 0.25 ° of visual angle. The temporal interval lies at less than about 100 ms (Larsen, 1983, p. 11) It appears that these are both necessary conditions for the short range-system to be engaged (Braddick 1980, p. 138) — not least the former condition, of an actual *short* range of displacement. And, a quarter of a degree

does indeed seem "short". Using a laptop as a provisory cinema screen, we can make some rough measurements of visual angle in film.

Visual angle is a measure of the relative size an object takes up in the visual field. Given enough distance, the moon can be sufficiently small in the visual field to be covered by one's thumb, for instance: The visual angle of the thumb exceeds or equals the visual angle of the moon. It thus depends on the variable of viewing distance, as well as the actual size of the object measured (the size of the screen, as we're interested in here). Since the optimal film viewing experience will present flat, frontally oriented stimuli to the viewer (i.e., not oriented in space), the following formula sufficiently describes visual angle (Gibb et al., 2016, pp. 46-47):

$$Visual\ Angle = 2 \cdot atan\left(\frac{\frac{Object\ Size}{2}}{Object\ Distance}\right)$$

As for a film example to use, I have opted to use Barry Levinson's *Good Morning Vietnam* (1987), starring Robin Williams in the lead role. Any film with standard, cinematographic parameters would be applicable here, so the choice is fairly arbitrary. Its capture on an analog film camera, with no special artistic ambitions for shutter speed (unlike *Saving Private Ryan*), should make it an apt choice. The choice of shots within the film, then, is also quite arbitrary. Having made a choice, however, we have to be very specific. At about 30 minutes and 10 seconds in, the movie is in the midst of a scene where Williams' character tries to give an English lecture to a class of South-Vietnamese students. Williams says the following lines, within the same shot: "*Let's try a little phrase.. Ah .. I like to call, my boyfriend's back and there's gonna be trouble, hey-na, hey-na, there's gonna be trouble*". The shot is more-or-less static, except for a slight detectable unrest in the camera's concentrating on one spot. Just at the point where he says "*I like to call"*, his left hand moves across the screen, skirting just under the word "CAT" on the blackboard in the background — which is useful to us as a reference:

Fig. 3.4: Robin Williams in Barry Levinson's *Good Morning Vietnam* (1987)

From the exact frame that this first screenshot is taken, we skip ahead *one single frame* and find his hand positioned thus:

Fig. 3.5: Robin Williams in Barry Levinson's *Good Morning Vietnam* (1987), one frame ahead of fig. 3.4.

Williams' is making a little "shrugging" flourish with his arm here, then, which is no violent or particularly rapid movement, but does have enough speed across the camera's lens to attain a modicum of motion blur — as seen in the stills above.

The following measurements, then, were done on a screen surface measuring approximately 39.2 cm, diagonally. That is the diagonal of the surface of the movie frame itself, which has an aspect ratio of 1.85:1 — as opposed to the diagonal of the computer screen on which it was viewed. (The movie's frame, while close, did not quite fit perfectly within the aspect ratio of the screen itself, in "full screen" mode). Under these conditions, using the soft contour of Williams' *index finger knuckle*, I measured that it displaces approximately 1.0-1.1 cm. His hand traces a slightly curved movement right at this moment — measuring from closer to his wrist, just above his watch, the distance becomes about 0.4-0.5 centimeters.

As for viewing distance, we could posit a range different, applicable numbers. Sitting in typical working distance from a computer screen, placed on a table top, the distance from the eyes to the screen may be in the proximity of 60 centimeters. Considering how the movie frame (of the prior specified dimensions) fills the field of view, in this circumstance, this might correspond to viewing a cinema theater screen at a comfortable medium distance. Using these numbers, we get:

$$Visual\ Angle = 2 \cdot atan(\frac{\frac{1.100}{2}}{60.000}) = 1.0504^\circ$$

$$Visual\ Angle = 2 \cdot atan(\frac{\frac{0.500}{2}}{60.000}) = 0.4775^\circ$$

Even if we accounted for any vagaries of measurement here, it does not seem that this could put us even close to the quarter-degree-mark specified by Larsen et al., and Braddick. Meanwhile, some movement in the film *would* presumably do so — based on what is being measured (Williams' rather marked gesture). Other movements still may be close to lying directly on the boundaries. This would continuously depend on viewing distance, i.e. the size that the screen has relative to the field of view. We could imagine a viewer to gain a relatively closer view, at the front seats of the theater, which would drive visual angle up — and vice versa.

It seems slightly puzzling why Anderson and Anderson exclude this possibility, of cinematic motion exceeding the limits of the short-range system. My research on this topic has not been successful in locating any sources refuting their point with regard to cinema — or a later take on these details by the authors themselves. They relay Braddick's limit of 0.25 ° for short range movement (1993, p. 8), yet one footnote (ibid. p. 11) holds that "The spatial displacement from one frame to the next (generally less than 15° of visual arc), falls well within the parameters of short-range apparent motion.". 15 degrees is a great leap — a common rule of thumb is that the width of one's thumb, held at arm's length, is equivalent to two degrees (O'Shea, 1991, p. 415). Although degrees (°) are clearly stated in said footnote, there might have occurred a mix-up between the measurement of angle in degrees and *arcminutes:* 15 minutes of arc — which would be notated with a prime (′) — corresponds exactly to a 0.25° angle. Regardless, the contention here remains that it seems very conceivable for the 24 fps motion picture to go beyond this quarter-degree, under regular, favorable viewing conditions.

What could this mean? It seems that the more "higher-level", "interpretative" mode, for the visual system's seeing of movement, *need not* be a stranger to cinema as we know it — interspersed as longer-reaching movements are likely to be with shorter ones, based on the film's particular depictions. The main thrust of interest that this delivers, to the specific concerns of this chapter, is the suggestion of a possible linkage — a linkage between the phenomenal experience of traditional film, and the activity of a brain in a "higher-level" mode of processing apparent motion. Granted, establishing exactness in such linkages seems like a formidable challenge. On one side of this would lie the complex workings of the brain, to the degree that the science can shed light on them, and on the other side the intangibilities of first person experience — experience of 24 fps film as "heightened", "striking", affective somehow — those diffuse characteristics (inescapably so) suggested in the introduction: a pleasant "veil of unreality". Gaining specificity, in connecting the activities of the brain with such subtle apprehensions, would seem to be a very tall order — even if one makes use of a deep expertise on the science of the brain. (Which is, to be sure, not part of the repertoire of this author).

Nonetheless, setting these difficulties aside for a moment: Along with general assessments that the visual system operates more interpretively, and more on a "high-level" processual level with long range movement, we may also point to studies such as the one by Zhuo et al. (2003) — which considers both the perceptual capacity for interpretatively seeing shape

"transformation" of an object across long range A.M., and the specific activation of neural systems associated with form processing. For something significantly *different* to be engendered, by long range A.M. interspersed throughout film — on the experiential level, and compared to real-life "smooth motion" — emerges as a highly interesting and pertinent notion. Also, while 24 fps may not be "fast" enough to divest itself of long range A.M., a drastically increased frame rate such as HFR 48 fps may well be capable of doing so.

If we are to bring on board the assumption that short range A.M. is in some sense cognized as indistinguishable from "real motion" — while also being wary of a conceptual conflation between the two, as mentioned earlier — this could also be a very interesting addition to the phenomena explored in the chapter two: specifically, the pull toward seeing a more "immediate reality", of some kind, with HFR. Granted, this also depend on drawing links between objective descriptions of the workings of the brain, and somewhat diffuse qualities of subjective experience — a sense of "liveness" to the images. The key point here would be that images exhibiting a smoothness of motion — which appears to play a crucial role in inducing this effect — may not just lay incrementally closer to real motion through its "gaplessness". The smoothness may also put it on the other side of a boundary where a different, more direct "ruleset" for processing motion applies — one that is fundamentally linked to seeing motion in the real world. Such a crossing of boundaries may offer an additional means of accounting for why this seemingly slight visual change to film motion appears to have such a powerful effect, in coating the images in a sense of "immediate presence" — going beyond just the televisual "codes of realism" (Turnock 2013, p. 45) that smoother motion percepts are associated with. One is beholden here, however, to positing the scenario that a more direct processual pathway for motion in the brain bleeds into a conscious percept — of greater "directness" and "presence" to the moving film — which is not settled, and may be very hard to settle.

The role of motion blur

With the actualization of these specific considerations of how objects on film move, from one frame to the next, this should be an apt point at which to also give some further consideration to the motion blur that accompanies and "varnishes" these movements — or does *not* do so, potentially, depending various conditions. As I will try to show, motion blur appears to play a role in issues of frame rate that may not be entirely straight-forward, and carries some

potential for complication. It also warrants some attention in order to further qualify the above examination and measuring of distances, in frame-to-frame movement.

Firstly, in recent times, modern *digital* cinema cameras appear to have provided us with a demonstration of what a "filmic" aesthetic looks like if the parameter of shutter speed is altered in a direction that was previously impossible — namely, toward a maximal exposure of light, for the entire duration of a frame's recording. To recapitulate slightly: traditional film cameras are limited to a 180 ° shutter speed, or exposure time of 1/48th of a second. This is because light has to be closed off for half of the time, to allow for the transition of the next frame into the appropriate position for exposure (Iseli and Loertscher, 2016, p. 3). A modern digital cinema camera has no such barrier. While other aspects of the digital image can remain finely calibrated to achieve a "film look", exposure time can be set to 1/24th of a second, significantly increasing the amount of motion blur — and thereby smoothening the motion of the film. The effect of this, it may be suggested, is that motion blur *alone* goes a significant distance in stripping films of the "sheen" of their "cinematographic effect" — as Julie Turnock (2013, p. 47) puts it, with regard to HFR. This may require rather discerning eyes, to catch an "unorthodox" amount of motion blur. At the same time, various complaints to that effect — that the "film look" is compromised — are found on the world wide web, such as a colorful YouTube presentation by Swedish filmmaker Erik Engbo (Standard Film Team, 2015), with ample exemplification from contemporary Hollywood films. The highly recognizable sentiment here is that those films, which opt for digitally-enabled slow shutter speeds, look "bad" or "cheap" as a result. (i.e. some manifestation of the "soap opera"-look). This could perhaps be seen as positing an up-front challenge to the notion that there is anything inherently "special" about the 24 fps film aesthetic as we know it — beyond its conditioning as the look of cinema: If merely an extra amount of motion blur and smoothness serves to significantly undercut the sensation of 24 fps as the "rarefied" domain of cinema, how could this rarefication be more than relatively superficial? A hypothetical answer to this may in part leverage the ways in which HFR and "blur-rich" film remain quite dissimilar from one another — with HFR's "hyper-clarity" and "hyper-sensitivity" of motion being more emphatic aesthetic effects overall — as well as the concession that a highly specific conditioning of a codified "film look" *is* indeed very likely to be operant, especially in more discerning viewers. However, such a challenge also opens onto a further consideration of *similarities* in how very different cinematographic means (HFR and blur) seem to enact similar aesthetic effects — a smoothening of motion — which could be significant to us here.

Looking at the earlier still frames of Robin Williams (figs. 3.4 and 3.5), we can see that some motion blur has begun to take hold and "soften" the boundaries of his arm. Given a faster movement still, across the camera lens, one would expect solid boundaries to give way to a wider, more disintegrated "smear" of the arm across the frame. Locating such an instance, elsewhere in the film, this can be demonstrated. At around 41 minutes and 55 seconds, right after Williams says the line "*No, Pope Paul VI celebrated a mass in Italian*", he makes another upwards gesture with his left arm:

Fig. 3.6*:* Robin Williams in Barry Levinson's *Good Morning, Vietnam* (1987)

Here, as the arm is in the midst of a movement toward the edge of the frame, we see that it has taken on a more indefinite, more transparent character than what was seen in the previous example. For the time interval in which this single frame was up for recording, the hand moved over a comparably greater area of the film. This allowed light (or *more* light) from the background to enter the areas of the frame which the hand occluded just before — seeing as how it moved quickly out of that area, within the time in which exposure occurred. Also, the hand registered its faint presence at the outer boundaries of the movement it made within that time, where light from the background got more exposure. As the hand slows down, in the following frames, the hand gains seeming corporeality again:

Fig. 3.7*:* Robin Williams in Barry Levinson's *Good Morning, Vietnam* (1987), a few frames later than fig. 3.6.

Had the exposure time been *doubled* here (as would have been possible with a modern, digital cinema camera), it follows that the effect described with the first frame would have been exacerbated: more light would have had the time to flow in from "behind" the hand, a faint imprint of it would be seen *further* to the right (i.e. Williams' left), and so on. Had a very fast shutter speed been used, however, the form and appearance of the hand would likely be more distinctly arrested in each frame. Importantly, strong instances of movement is needed for these differences (of shutter speed) to fully come to light. If there is little movement taking place, the difference between 24 fps at 180° and 360° shutter speed may become significantly harder to spot — objects gain a highly distinct exposure, regardless of exposure time.

It emerges as an interesting point how this should be mapped onto the previous incursion into measurement — of distances between discrete, single-frame steps of a film. Under some conditions, there doesn't seem to be much difference to consider here, between a traditionally shot film, and one utilizing significantly more motion blur. Both may present us with moving objects that are softened by some motion blur, yet present a rather clear contour — which appears fairly unproblematic to take as definitive, more-or-less, of where to measure the distance of movement from one frame to the next. The instances from *Good Morning Vietnam* that has already examined, and measured, would be an example of this. In other instances, conditions are such that motion blur becomes very manifest — which applies to both 180 °

and lower shutter speeds, although more easily with the latter. In the most blurred capture of Williams' hand (fig. 3.6) his fingers have become very faint in their "smearing out" across the still frame. Should we consider their movement, from this frame into the next, to start at the faintest, rightmost trace of them — or from a slightly more solid area, more to the left? The darker backside of Williams' palm seems like a more unequivocal point from which to define the beginning of a discrete movement. With greater motion blur, however, this shape and edge may also become more widely and diffusely spread out.

Under real-world circumstances, motion blur is a taking place on the retinas themselves. If we optimally track a movement of a car with our eyes, it is held in the center of the retina, and is not blurred. If a car rushes past us while our eyes are fixated on something on the other side of the road, it will "smear" or "blur" across the retina. Going from this to the filmic vision of *discrete* displays of motion-blurred objects, it may not seem entirely apparent what is perceptually occurring, in place of the real-world, smooth-motion phenomenon. Presumably, in its interpretative and organizational efforts, motion blurred images are a familiar phenomenon to the visual system — even if the blur is recorded prior to the retina, on the film. What seems evident, at least, is that this blur is readily made use of to yield a smoother flow of images, in a situation where sharp images would have created a more "unsmooth", sensation. If we take as a working assumption that the brain sees the faint, outermost "smears" of an actor's hand as workable information on its location in space, it could follow that motion blur (and the amount of it) may indeed play a significant role in making 24 fps *skip shorter distances ahead in space* — bearing implications for long-range and short-range apparent movement.

An online, schematic demonstration from camera manufacturer RED (2018), on the effects of shutter speed, may serve as a useful illustration here. As three successive frames of a moving ball gains more motion blur, they come ever closer to connecting in space:

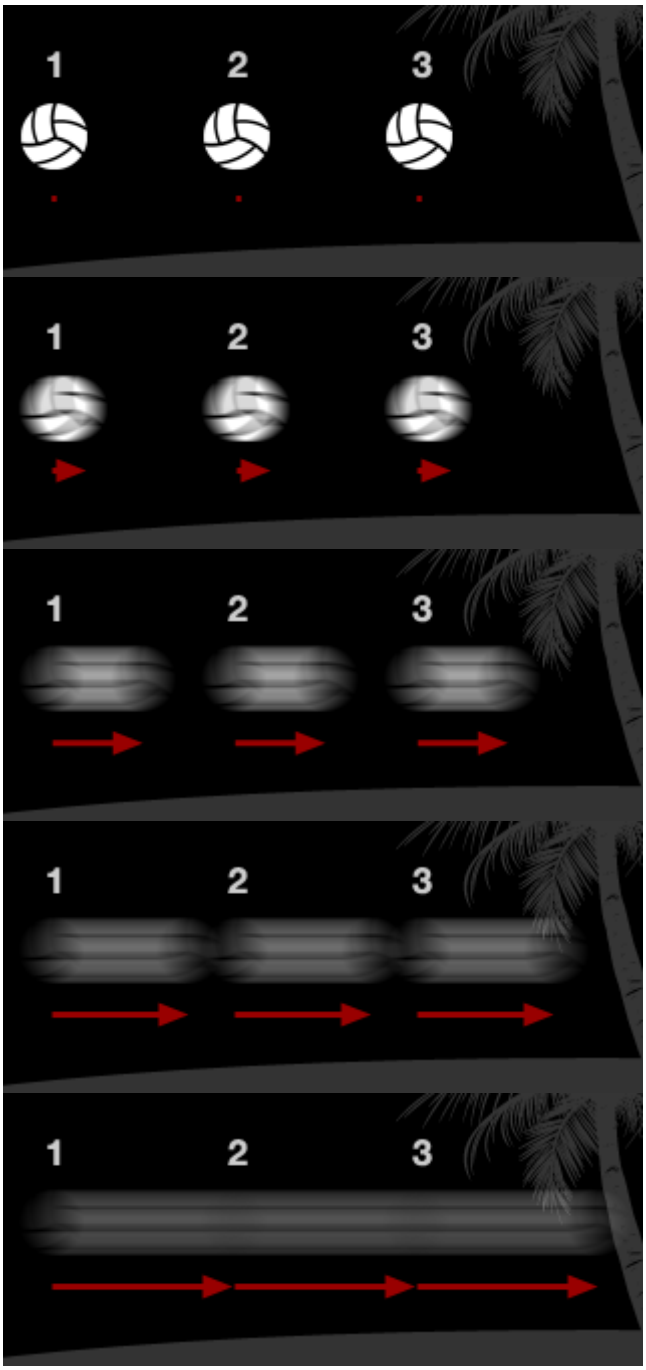

Fig. 3.8: Motion blur illustration from website of digital camera manufacturer RED (2018)

Meanwhile, a moderate amount of blur may retain a significant spatial distance between the successive images, as opposed to a full amount.

Provided this assumption being correct (or sufficiently correct), then, this may allow us to gain a view onto how the visual system could similarly treat both HFR and *particularly blurred* 24 fps more like "real motion" — or at least *short-range* apparent motion — compared to their more traditional 24 fps (180° shutter) counterpart. This rests on that assumption about film's peculiar visage of motion blurred objects, however, and should be

seen as an invitation to further research — both spanning and reaching beyond the specific issues that are activated in this chapter. (There may also be existing, relevant expert knowledge, that I have not been able to bring to bear here, that could fruitfully enter into the picture).

24 fps and a "Less is more"-principle

To end chapter three, I will present and discuss some ideas that generally move the inquiry beyond the particulars of movement that have characterized the above pages. There is a notion of *reduction* of picture information that run through those concerns — the leaving of "gaps" for interpretation, and so on. Such reduction can also be conceived of in more straight-forward terms, however — more directly reflective of the "face value" experience of seeing more *detail* unfold in an HFR image. This was, to recall, important to some points raised in chapter two, such as those pertaining to artificiality and its "unveiling". While not entirely divested of the prior perspectives in chapter three, it is more on those terms that this last segment will consider some further, possible implications — for the very visible modification that a higher frame rate makes, on the amount of information contained in the cinematic image. Specifically, frame rates will be brought to bear on a question of what affinity cinema generally has, in potentially all of its stylistic aspects, with an aesthetic approach where "less" tends to mean "more" — where *reduction*, in a broad sense, is a desired state of affairs.

Effacing the superfluous

It may be remarked up-front that the notion of "hiding", of artificiality or fakery, is *one* way to conceive of a practical, inherent *advantage* of the traditional frame rate. To the filmmaker, reduced image detail may in this way provide greater leniency to the demands put on mise-en-scène. In conjunction with a referral to the possible caveats to the phenomenon, treated in the previous chapter, this will only be mentioned and "catalogued" here.

Beyond this, more picture information may also provide challenges of a more artistic nature — not pertaining to the exclusion of signs of artifice, but rather the exclusion of that which is in some sense excessive and/or unnecessary to the film's communication. This implicates style as well as narrative: superfluous elements of mise-en-scène and cinematography, as well as shots, scenes and dialogue.

This notion, applied to HFR, does not originate with this thesis. Through the journalism and criticism on *The Hobbit* and HFR film, there are streaks of such a perspective to be found. In one take on the topic, Vincent Laforet offers the following thoughts:

> In my opinion, film is not necessarily about what you see—but it's almost more an exercise in what you don't or can't see. The best directors and DPs show you only what is relevant to the story and never introduce a random shot or character if they can at all avoid it. I've always preached that a director or photographer should include elements in a frame or shots that add to the story, and exclude elements or shots that detract from it.
>
> (Laforet, 2012)

This may invite a range of considerations, on how stylistic features of movies (which lie closer to us here than narrative), may be subject to such a principle: Despite its niche status today, black-and-white film photography may still be sought after for a certain "striking" effect. In color film, the filmmaker may still be hard at work to discipline the color scheme of a given shot, in production as well as post-production. A shallow depth-of-field is very directly implicated in "blotting out" parts of the picture that is less essential, compared to a character or object in focus. Although often containing many elements at once, sound is also distilled and focused — with emphasis on dialogue, if any — to avoid an indiscriminate cacophony. One could perhaps even attempt to extend this notion to aspect ratios, with the narrower Cinemascope format, preferred in Hollywood, eschewing information in the height dimension of the picture plane.

With regard to how HFR could add itself to such a perspective, on more specific terms, we might draw attention to certain characteristics of its hyper-sensitivities of motion: when there is not much movement of consequence in a shot, such as with a still-standing actor, HFR capture may still record and exhibit more acutely the fact that there is always *some* minuscule movement taking place. Attention and engagement in a given moment, narratively speaking, may ideally lie with the attributes of an actor's facial expression. Hyper-acute motion recording may, however, draw greater attention to the *slight* restlessness of the actor's silhouette against the background, or even the slight restlessness of the frame of the picture, if the camera was not held perfectly in place. Effacing such motion, in favor of a greater calm and/or focus, may be an effect that is broadly sought after, artistically — and 24 fps, through a more "dulled" recording of motion, may be a means to this end. On the other hand, HFR

could inherently excel at capturing subtleties of facial expression, which could have artistic utility — although this may also be superfluous, in some sense, owing to the acute sensitivity humans already have toward faces and facial expression. The case of actors and faces are especially interesting on account of its ubiquity in film, but also, perhaps, in relation to an idea investigated in chapter two — that HFR, based on reports such as that from Richard Corliss (2012) fared worse in typical "dialogue"-scenes than in vivid action-scenes. While the latter foregrounds and revels in kineticism, the former does not — and may thereby be seen to suffer more from not keeping superfluous motion "disciplined".

Iseli and Loertscher (2016) contribute some experimental findings on user *attention* while watching high and standard frame rates, which could be relevant to the above issues of attention and narrative focus. Tracking eye movements on participants viewing short clips of film, which were identical save for frame rate, Iseli and Loertscher observed different ways of engaging with the motion picture. A higher level of visual "exploration" of the picture was found with the highest frame rate of 96 fps. This came at a certain cost of focus on the central features of the image, such as a bicycle-riding "protagonist" character in one of the clips. (ibid., p. 5). In accordance with our concern with the role of convention and conditioning in this chapter — and possible roles played by factors distinguishing themselves from this — it becomes an important question whether such an effect owes something to the mere *novelty* of HFR cinema: Its unaccustomed vividness could prompt new viewers to explore the unprecedented clarity on display, thereby yielding the effect observed. Conversely, however, these findings also enable the question of whether HFR somehow prompts the visual system, on a more fundamental level, to engage with the picture differently. Further and greater audience exposure to HFR cinema is perhaps needed to separate and isolate a possible "novelty" factor.

One element that the study found participants to be paying more attention to, specifically, were moving backgrounds — panning behind a moving foreground character, for instance. In a standard frame rate (at a 180° shutter speed), such a background would be obfuscated both by in-lens motion blur *and* the kind of blur that has been termed *judder,* in chapter one. In other words, one wouldn't here even need to resort to a shallower depth-of-field, to gain a natural separation of "foreground" and "background". This could point up a more general propensity of the standard frame rate, by way of blur, to distill and emphasize what is kept relatively static in a shot. Consider, for instance, the face and head of a boxer throwing a punch, relative to the punching arm that moves faster across the lens. This may not map onto

directorial intentions for what is most narratively important, on a given occasion — but seems to continually bring in a potent effect, in fast-moving shots, of some elements being emphasized over others. On the other hand, HFR enables the possibility of seeing "everything at once", in vivid detail. This ties into its touted appeal, of unprecedented image clarity, but may also come at a certain cost to the opportunity for artistic, visual orchestration of "essentials" in the moving picture.

A formalist perspective

From the above points, one can perhaps already begin to anticipate how a "formalist" position on film could approach the main task that has been set in this chapter — that of locating possible accounts for why film may share an affinity with standard or "low" frame rates.

In one sense, "formalist" describes a contemporary theoretical perspective concerned with film form and its effects on audiences. (As such, this thesis has employed a mostly "formalist" perspective, from beginning to end). What I specifically intend to evoke here, however, is "formalism" in a related but more specific sense: that of the early branch of film theory that signaled its opposition to a "realist" counterpart — with exponents such as Sergei Eisenstein (and other Russian montagists), Béla Balász and Rudolf Arnheim. The "formalist" line of thought famously espoused strong skepticism toward "realism"-inducing innovations such as synchronized sound. This, arguably, bears a clear thematic linkage to our subject here. (Most such innovations would appear to be based on *adding*, as supposed to *subtracting* something from the experience). Arnheim's (1957, p. 154) writings are particularly representative of a dismissal of sound-film, for instance — as a positive or essentially important addition to film art. While sound, through "sheer good luck" could offer something beneficial to cinema, its realist pretensions to "mechanical imitation of nature" also ran the risk of destroying the art (ibid.). In Arnheim's view, film excelled as art when operating on its own, medium-specific merits, and certainly not when placed in subservience to other art forms or to "imitation of nature", as espoused by the realist position. Perusing his seminal work *Film As Art* (first published in 1932, expanded in 1957), one finds a rich array of related positions that can seem almost ready-made for extrapolation to a technical innovation that Arnheim *didn't* get to see in his life time — the one under discussion here. Perhaps somewhat antiquated in a contemporary view, but still very interesting to us here, we find color on film described as "incapable of controlling its multidimensional instrument", having "never gone beyond tasteful "color schemes" (ibid., p. 5). Stereoscopic 3D, on its part, deprives images of the

favorable, irrealistic ambiguity inherent in fastening three-dimensional scenes onto two-dimensional planes (ibid., pp. 12-13). Black-and-white photography recasts the world in its own abstracting terms, turning leaves on a tree "as dark as a woman's mouth" (ibid., p. 15). The filmic images achieve artistic saliency precisely *for* their unreality, in the formalist view — for the ability to re-present the familiar in a way so as to prompt an unfamiliar way of looking at them, differing from the prosaic real-world apprehension of things as transparently "themselves". One could go on at length, in quoting Arnheim on how he lays down this core view on how art achieves art — as opposed to fighting a losing battle to replicate reality (ibid., p. 5). This seems sufficient to take the matter over to HFR, however — an endeavor which seems to be saturated with promise, in light of the above, even if it might not be immediately clear where focus should be placed.

Firstly, from what has been investigated in this thesis, there are some indications that HFR indeed could deserve some claims made for it, of being more "realistic" — in a particular sense of "perceptual realism", as was treated in chapter two (page 70). The discussion of frames, blur and motion, earlier in this chapter, could suggest that HFR places motion significantly closer to being apprehended by the brain as if "real-world" motion. Traditional film motion, however, may have a slew of attributes which resonate with James Cameron's description of a "veil of unreality". Traditional film images can be thought of as quite peculiar, maybe surprisingly so, in how they move in relatively wide, discrete steps of 24 fps, all while being individually coated in a particular amount of motion blur — a motion blur which exists *prior* to blurring on the retinas of the viewer. This kind of configuration appears quite inconceivable in real-world visual experience. To see the overall result as abstracting and/or de-familiarizing of objects in motion, as well as motion *in itself*, does not seem implausible.

A contrary viewpoint here may point out that motion with the potential to "startle" the viewer, in its vividness — as HFR might produce — hardly seems to be tritely realistic, or lacking of an unfamiliarity itself. This may indeed be a fair contention. A possible answer to this could be that an increased perceptual realism — an aspect of the experience that has a reasonable claim on looking *more* like the real world, such as color versus no color — is confused with an unattainable and ill-defined goalpost of "ultimate" realism. Any awareness of mediation would be considered a deeply unrealistic and unfamiliar experience to have, as seen in light of a situated, immediate experience of the real world. HFR may have been startling to some audiences *for* its realness, and thus perhaps for being all too familiar, paradoxically.

Presumably, the chromatic exuberance of the Technicolor film process could have had a striking unfamiliarity to unprepared audiences in its day, while not upsetting Arnheim's point about color film.

Distillation and "psychological realism"

Finally, there is one slight tension to this formalist position that could benefit from some disentanglement. While there is the commonplace experience of real-world phenomena, chairs and tables, which lacks the potential unfamiliarity of their representation in film and photography, it is not as if the perception of the real world lacks its own concentration or distillation:

> That is to say, in real life we are satisfied to take in essentials; they give us all that we need to know. Hence if these essentials are reproduced we are content and obtain a complete impression that is all the more artistic for being so strongly concentrated.
>
> (Arnheim 1957, p. 29)

The assertion that our vision onto the real world is fraught with its own, mental formativeness — Arnheim was a proponent of Gestalt psychology (Verstegen, 2006, p. 1) — might open up to a certain re-framing of a proposed formalist take on frame rate. Together with other means of reducing and distilling information in the picture, 24 fps may contribute to a certain conferring of a *psychological* realism to the movie experience. To illustrate what is meant here, we may return briefly to the issue of superfluous motion: Why is it that a "bobbing", "hand-held" sensation to camera movement could potentially upset viewers' wishes and desires for an appropriately "cinematic" expression in film — while the similar down-up-movement of our eyes, as they are carried along by our walking bodies, do not phase us whatsoever? In the latter case, this up-and-down motion is ignored, filtered out by the brain. Film and media theorist Vivian Sobchack provides us with the notion that a film is not only an object for experience, but simultaneously a subject *of* experience — an experiencing subject in its own right: "More than any other medium of human communication, the moving picture makes itself sensuously and sensibly manifest as the expression of experience by experience". (1992, p. 3). One way to conceive of this, it seems, is that the film-viewer latently presupposes that the film experience is to be an experience *of* experience — the film's *own* experience, owing to the camera's evocation of the subjective outlook of an experiencing subject. In such a view, it may be deeply ingrained, in our fundamental expectations for film,

for it to come to us "pre-distilled", "pre-concentrated". This could depend on a multitude of stylistic factors, including ones where a contribution from a low frame rate — a *relatively* low one, that is, such as 24 fps — may be quite consequential.

Conclusion

The treatment of the open-ended research question of chapter three has found itself under the pull of ideas which, through the insights garnered from their discussion above, could be seen to emerge as a rather unitary and interlocking construct: *Less* information, as provided by a lower frame rate, can have significance for *more* participation and greater engagement with film — extending into both conscious and unconscious mental processes. This could owe to said frame rate's "opening" of more interpretative space for the viewer to work with, and also a greater disciplining of the salient amounts of information that *will* be offered up for this engagement to take place within — contributing to a focused, distilled entry into the moving film. This last aspect, on providing artistic focus and distillation, emerges as a fairly concrete and compelling perspective on how the classically dispositioned filmmaker in particular — endlessly dwelling over his or her material, to make it as focused and economically communicative as possible — may remain partial to the traditional 24 fps frame rate.

As for the particular issue of the viewer's interpretative engagement, with the spaces in-between the frames of film, this proved quite challenging to penetrate — perhaps not surprisingly. This chapter's first main foray into 24 fps, by way of even slower and still-standing "filmic" expressions, provided considerable interesting material for discussion. This material appears to be quite pertinent, even essential, to bring into a complete consideration of the particular properties and potentials of the 24 fps format — even if it does not, in itself, open for any conclusive assertions. It lends interest to, and also receives interest from, the subsequent branch of investigations in this chapter — into the possible significance of traditional film affecting a particular "long-range" system for motion in the brain. This issue also becomes difficult to bring assertiveness onto — particularly with regard to a linkage between the workings of the brain, and vague, subjective sensations associated with film viewing. At the same time, the issue of long range motion could be seen to draw remarkably close to the notion of a *biological* underpinning, for why 24 fps may give the impression of being somehow "heightened" and pleasantly "unreal" — placing the cinematic image into a different register of psychological effect, compared to other moving images. This *type* of answer, to the open formulation of the chapter's research question, was imagined as a

potential — but expectations for it to actually materialize, to any degree, were quite low. This explorative incursion, into the possible phenomenon of long-range apparent motion in film, does not in itself constitute a clear example of such a materialization. It arguably spurs considerable interest in that direction, however, which should warrant further research and discussion. Particularly, the disagreement with Anderson and Anderson (1993) signaled here, on whether long range motion is actually a part of 24 fps film, under normal circumstances, is open to further input.

Thesis summary

Conclusion on research question

Main research question:

What effects do HFR formats have on viewers' experience of cinema, and why does it have these effects? What conditions do these effects pose for the possibility of a future breakthrough of HFR cinema, after a difficult beginning?

In the introduction, I indicated a broad dichotomy of two aspects that related to the question of the mainstream adoption of HFR for cinema: on one hand, there was the *drive* to adopt the technology — the reasons for which appeared to be particularly centered around the issue of *viewing comfort* in the cinema experience. On the other hand, there were the *obstacles* this drive encountered, with the backlash to the new aesthetic that HFR conferred on film. Chapter one endeavored to assess the nature and the magnitude of the drive, whereas chapter two was intended to speak to the obstacles — with an initially open and unascertained contribution from chapter three, to a view onto such obstacles.

The conclusion reached in chapter one held, in brief summary, that while viewing comfort was indeed an apt justification for the drive to adopt HFR technology, it did not appear to fully live up to the strongest promises suggested for it in this regard. If HFR technology holds an indispensable solution to the overall complex problem of 3D and viewing discomfort, there appears to be a need for a much clearer communication of the exact, technical nature of this. As this stands, it appears that 3D viewing comfort can be improved significantly by means other than changing the frame rate — without the risk of ignoring a core hurdle of eyestrain or discomfort that is specific to 3D, and which only HFR is positioned to remedy. HFR's significance for viewing comfort *in general*, however, regardless of 2D or 3D, gains weight with the observation that motion artifacts are not likely to disappear through other means than increasing frame rate. Visages such as severely "juddering" camera pans may be quite unpleasant to behold, even if they do not drive a uniquely disturbing percept in 3D.

From the conclusions of chapter one, there is some cause to moderate the "viewing comfort"-argument for the adoption of HFR film, placing added emphasis on the need for audiences and filmmakers' goodwill toward the aesthetic and "look" of HFR cinema. Arguably, this especially pertains to the professionals devoting much of their lives to making movies, and

who are likely to offer a deep and intent gaze to the material they are working with. If the particular sensibilities of the moving image, offered by HFR, does not resonate with these professionals — does not reward deep attention with a desired effect and investment into the images — it seems unlikely that the reduction in blur and judder will offset such an obstacle to involvement in the craft. General audiences may to varying extents be concerned with said shift in cinematic sensibility, but it would be quite surprising if the film industry was not saturated with individuals that are visually attuned to the kinds of aesthetic effects that have been investigated in this thesis. If the hyper-smoothness and clarity of *Billy Lynn's Long Half-Time Walk* is not just to be acceptable, but also engaging, effective and *desirable* for its particular effect, it is perhaps a strong undercurrent of "live sports broadcast" that has to be embraced and mined for its qualities. From my investigation of that film, it emerges that such an approach — embracing the inherent "uncanniness" of the images — may be how director Ang Lee deliberately utilized the technology. Peter Jackson can appear to have been on a different kind of embracive path, with particularly video game-like segments of *The Hobbit: An Unexpected Journey*. HFR's powerful psychological pull, however — away from cinema and onto other conceptual states of the moving image — may be at risk of being significantly underestimated if the format is employed in a less assertive manner. When its greatly enhanced smoothness of motion runs through a scene such as the meeting-scene in Bilbo Baggins' home, it is seemingly not quite welcomed for the particular, powerful effect that it will nonetheless yield. In this case, the effect may be that of a "soap opera on steroids", in John Belton's wording (2014, p. 8) — owing to other stylistic aspects which do not particularly foster, yet do not outright deny the saliency of this conceptualization. Such is the apparent effectiveness of this smoothened motion quality — which, to be noted, is the aspect of the HFR aesthetic that we have gone a significant stretch in pinpointing as the key source of an initial, conceptual "wrench" out of the realm of cinema. This is also found with other media that exhibits this "gapless" sensation of motion, like the video cameras of BBC's *I, Claudius* — and a vast array of day-time soap operas, filmed with similar equipment.

HFR, then, emerges as a potent tool for the filmmaker willing to radically embrace its particular effects — perhaps at the expense of other effects, such as a useful means of distilling and focusing the film's expressive register (as explored in chapter three). Such distillation would be *undesired*, however, if one were to consciously aim to make a film about a "dystopian, modern revival of the Roman gladiatorial games, complete with 60 fps live broadcast", as evoked with the combat scene from *Billy Lynn's Long Half-Time Walk*. This

would generally be closer to the uncanniness suggested with that particular movie, however — likely more attractive to the appropriately dispositioned art-film director, than to the Hollywood "dream factory". (A Michael Haneke, more than a Peter Jackson). A movie that is radically like a video game, or like a rollercoaster ride simulation, may be more viable in a Hollywood blockbuster film paradigm. It remains to be seen, however, whether the industry is willing to eschew traditional stylistic devices — and the narrative conveniences that come with them — to the extent that may be needed for live-action film to avoid courting a "live television" and/or "soap opera" reception.

In joining chapter two to chapter three, there are some suggestions for how the liveness effect explored in the former chapter can be as effective as has been indicated — remaining potently there even in *The Hobbit*, where mostly everything is stylistically geared toward conventional cinema. While smoothly moving, photorealistic images have been associated with a certain "immediate" realism, stemming from television, there are indications that such smoother-moving images may also appeal more uniformly to a part of the human visual system — the *short-range motion* system — which is uniquely receptive to real-world motion: the kind of ideally smooth, "gapless" movement found in the real world. This could have ramifications for the insistency of this liveness-effect, where film characters gain a sense of looking "too real", like "actors on a set". Even as such an effect is mediated by learned conventions of television, it may be supported by a psychological effect from the brain seeing motion in a less interpretative mode, as immediately given, in a sense — as descriptions of the brain's short range motion system suggest. Traditional 24 fps' possible encroachment upon the long range system for motion, on the other hand, may conversely help detach live-action imagery from a primal sense of "immediate presence" — offering a slight "veil of unreality" in place of this, as was James Cameron's description. Meanwhile, it proves hard to settle whether such a perspective truly accounts for any of the liveness-effect of HFR, in no small part because of the challenge of tying the science of the brain with these somewhat intangible, phenomenal intuitions that are being investigated. There is much potential for importance in this perspective, however, for the notion that these can additionally stem from more inherent factors than conditioning to television's "codes of realism" (Turnock 2013, p. 45).

Together with chapter three's indications for how the particular "unreality" of 24 fps may present salient gaps in visual information, which unconsciously invite a more interpretative engagement with the moving film image, this may contribute to a picture of low frame rates as always presenting some particular entries into a distinct aesthetic experience — available to

those audiences that offer a deeper look onto film. Whether these entries would always elicit a response that is similar to the current appreciation of 24 fps is doubtful, culturally informed as this response is likely to be. They may however play a part, in accounting for how just how invested filmmakers and audiences seem to be — in precisely how motion pictures move on-screen.

Scope, theory and methods, final assessment

In developing and completing the investigations of this thesis — as they now are expressed in the preceding chapters — I hold that the perspectives and methods employed herein have generally proved sound and satisfactory, in enabling an answer of the research question. A qualification of this will follow below.

For the first two chapters, the delineation of their respective areas of focus have throughout the working process appeared to flow quite assuredly from the subject of HFR cinema itself, in conjunction with the overarching research question posed toward it. In order to consider the future of higher frame rates for cinema, it was crucial to consider possible *advantages* and possible *drawbacks* belonging to the technology, with regard to viewers' experience of watching film. There were heralded advantages to the new technology, and the substantial claims for viewing comfort seemed to remain uniquely significant among these, even in the wake of controversies over aesthetics. There were also drawbacks*:* namely those particular controversies, with recurring points of criticism to take up for closer study — as done in chapter two. The choice of scope, then, for the first two chapters, appears to have fundamentally proved appropriate — as was the initial hope. Chapter three distinguished itself from the other two through being of a more open-ended nature, and also being less straight-forwardly acquired from the prominent aspects of the discussion surrounding HFR cinema. I will make some closer remarks on the first two chapters, before arriving at an assessment of the third chapter.

A preliminary question during research, with regard to chapter one and its choice of focus, was whether the finished chapter's in-depth treatment of technical minutiae — on 3D and viewing comfort, motion artifacts, etc. — was truly necessary to attain a satisfying picture of the advantages of HFR (for use in the answering of the research question). As investigations into these matters escalated, and the strongest claims made for HFR and viewing comfort continued to remain elusive and hard to establish, this choice of focus increasingly appeared

to be justified: the possibility of only having a few introductory paragraphs, clearly summarizing the important relations of HFR to viewing comfort, became increasingly distant, as the topic continually proved hard to penetrate. Given the task of properly and deeply probing this topic, it seems that this necessitated the methodical approach of consulting and reviewing prior existing technical knowledge and research, provided by expert sources. An important aspect of this approach and perspective, it may be noted, is that its claim on natural-scientific objectivity — biological/ophthalmologic descriptions of mechanisms for eyestrain, etc. — entails that the conclusions I draw from it could be decisively upended by other contributions, belonging to the same perspective. There might be relevant contributions that I have not been able to locate and utilize, and which would signal different overall conclusions than the ones I have drawn toward here. It seems reasonable to hold the impression, however, that the most important facets of the topic were sufficiently taken into consideration. Any further work on the elucidation of this topic is actively encouraged, to any refinement or transformation of the overall picture that this may (hypothetically) entail.

Moving to chapter two, this chapter presented the prime opportunity to engage with HFR cinema in the form of textual analysis — formal film analysis, specifically. With the particular (and peculiar) reported viewer reactions, to what must necessarily have been some aspect of the formal qualities of these films, such analysis appeared indispensable from an early stage. This has not changed, at its completion and presentation here. Moreover, J.G. Butler's (by way of John Ellis') perspective on "liveness" and "immediate presence", of certain types of moving images, proved through its application to have a very pointed resonance with those viewer reactions pertaining to HFR film looking "live", "like actors on a set", and so on. Its initial insistence as a theoretical perspective, to foreground in conjunction with the formal analysis, has in this sense been borne out. While more detailed choices may well have been made differently — for objects of study, the focusing on soap opera, and more — this main choice and coupling of methods and theory appears crucial for the understanding of the subject.

Finally, for chapter three, its particular research question fundamentally enabled an open field of inquiry. Research could move in a range of different directions, potentially yielding very different results. The employment of a cognitive-scientific perspective here showed itself able to coax some fairly arresting points from a difficult topic — of what may (possibly) perceptually transpire, in the openings between the particular frames of film projection. This appears to have achieved an opening of a significant current of interest to the chapter

question, as well as the main research question. An entirely different approach may also have borne significant fruits, however. One possibility could be to leverage psychoanalysis with regard to a concern with unconscious processing, for instance. Meanwhile, it seems to have been an overall sound and productive choice to concentrate efforts on those particular notions that have been presented — enabled by a cognitive perspective. As for the final angle chosen, for the last part of the chapter, it appears that a formalist take on frame rate reasonably fulfilled expectations, for a potential cogency with which it could speak to the chapter's questions. We might imagine, as an alternative for chapter three, that a further incursion into a formalist and art-theoretical perspective may have taken precedence over a cognitive one. There could well be further, fertile ground to traverse in this direction.

The topic of higher frame rates for cinema is a novel one for scholarly attention, and there should be much potential for further, productive work on all its numerous aspects. Hopefully, this thesis has in its totality provided some interesting stepping stones for further insight, into a fledgling area for research.

Literature

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