Smooth Motion, Cinematic Look:
Reducing Judder in HDR with Locally Varying Frame Rates

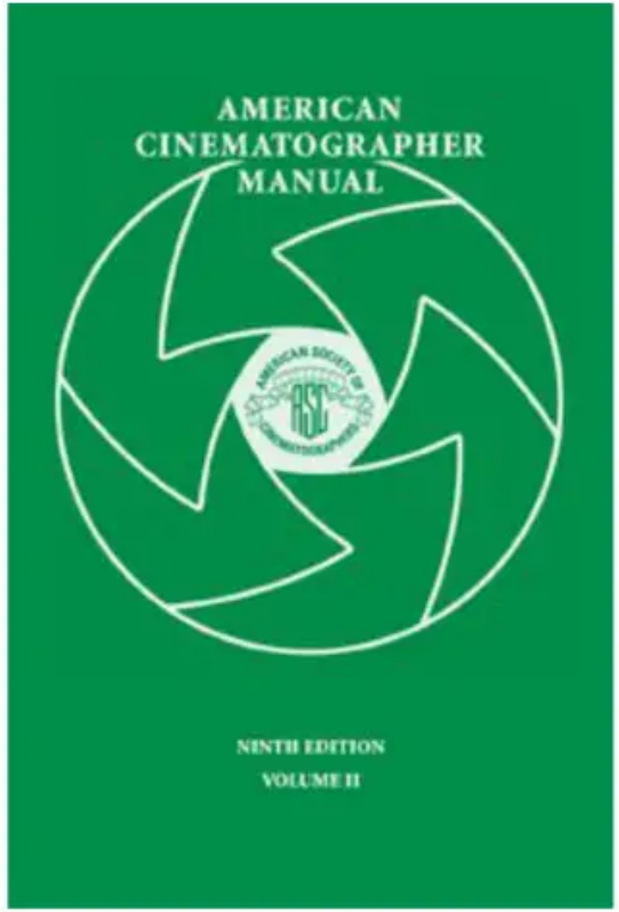
MITIGATE JUDDER - CAMERA PANNING SPEEDS

*"**24** frames per second **90° Pan** with a **50mm** Lens you should take at least **23s** for a pleasing motion look"*

35mm CAMERA RECOMMENDED PANNING SPEEDS AT VARIOUS FRAME RATES
Approximately 180° shutter — for static scenes

For 90° Sweep With Various Camera Speeds and Different Focal Length Lenses
EXAMPLE: 24 f.p.s. with 50mm Lens Should Take 23 Seconds to Pan 90° Sweep

CAMERA SPEED FRAMES PER/ SEC.	FOCAL LENGTH OF LENS IN MM										
	18 to 20	25 to 28	35	40	50	75	85	100	150	180	300
	PANNING SPEED										
	Unshaded Numbers: Seconds								Shaded Numbers: Minutes		
8	27	45	55	60	1.5	2.0	2.5	3.0	4.0	5.0	7.0
12	18	30	36	42	54	70	1.5	2.0	2.5	3.5	5.0
16	13	23	27	32	41	55	70	1.5	2.0	2.5	3.5
20	11	18	22	25	27	43	60	70	1.5	2.0	3.0
24	9	15	18	21	23	36	50	60	80	1.5	2.5
32	7	11	14	16	20	27	38	45	60	75	2.0
48	4.5	7.5	9	11	13	18	25	30	40	55	75
60	3.5	6	7	8	11	14	20	24	32	40	60
75	3	5	6	7	9	12	17	19	26	35	50
90	2.4	4	5	6	7	10	14	16	21	29	40
120	1.8	3	4	4	5	7	10	12	16	22	30
150	1.4	2.4	3	3.5	4	6	8	10	13	17	25



Source: American Cinematography Manual (p. 815).

HIGH DYNAMIC RANGE (HDR)

HDR Displays:

- Darker darks
- Brighter brights
- Increased Luminance

25 FPS - Standard Frame Rate (SFR)

50 FPS - Higher Frame Rate (HFR)

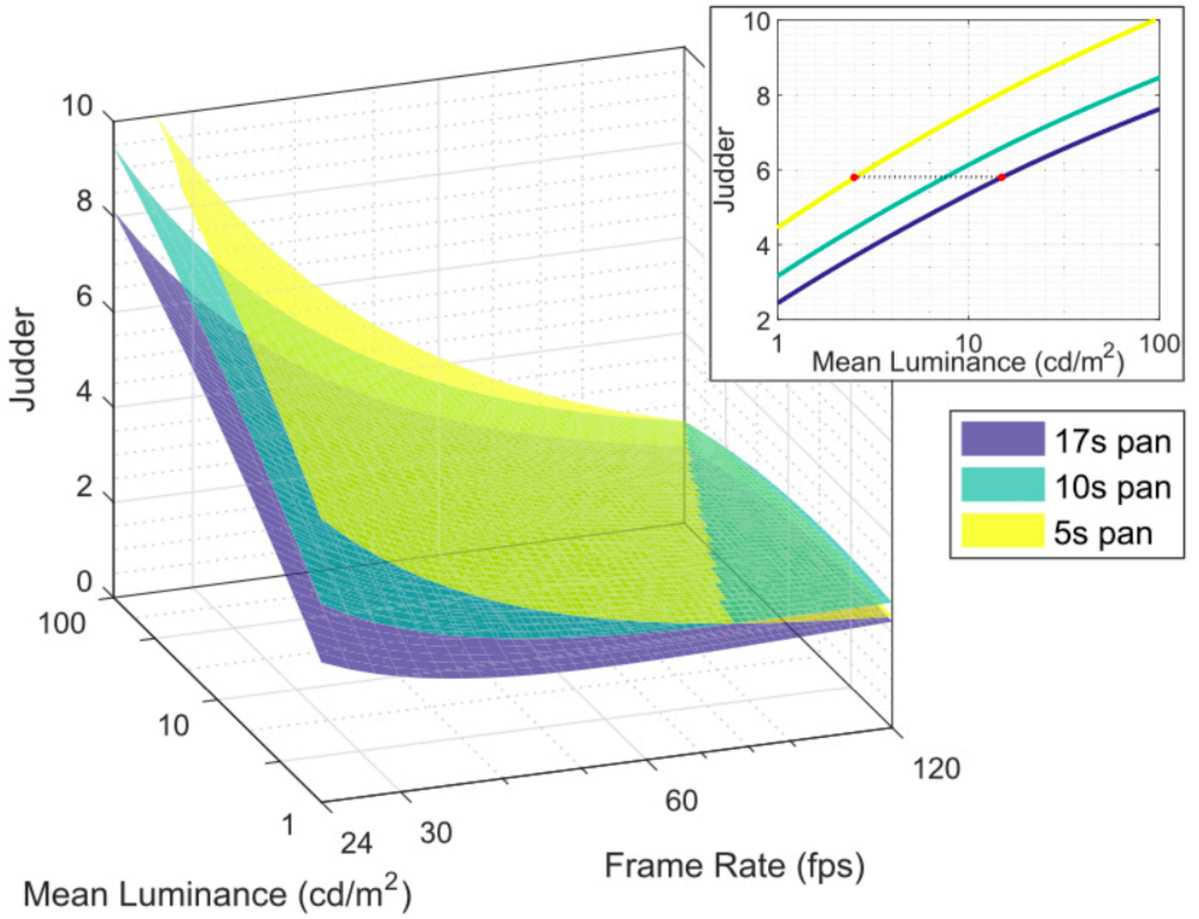
Classic Cinema Look

Higher Frame Rate

Can we remove unwanted judder (especially) in HDR content and keep a cinematic motion look?

A Luminance-aware Model of Judder Perception (Chapiro et al.)

- Model for Judder Perception
- Based on Mean Luminance, Frame Rate and the Average Speed of the Clip



Emulating displays with continuously varying frame rates (Templin et al.)

Emulating Displays with Continuously Varying Frame Rates

Krzysztof Templin[1] Piotr Didyk[2,1] Karol Myszkowski[1] Hans-Peter Seidel[1]

[1]MPI Informatik [2]Saarland University, MMCI

Figure 1: *Using different presentation frame rates yields different looks of the motion picture: higher rates reduce visibility of artifacts such as strobing and judder, whereas lower rates contribute to the "cinematic look" of the film. We introduce a technique that enables emulating the look of any presentation frame rate up to the display system frame rate. The frame rate in the content processed with our method can vary continuously, in both the spatial and the temporal dimensions.* Deer *sequence: (CC) Jeffrey Beach*

Abstract

The visual quality of a motion picture is significantly influenced by the choice of the presentation frame rate. Increasing the frame rate improves the clarity of the image and helps to alleviate many artifacts, such as blur, strobing, flicker, or judder. These benefits, however, come at the price of losing well-established film aesthetics, often referred to as the "cinematic look". Current technology leaves artists with a sparse set of choices, e.g., 24 Hz or 48 Hz, limiting the freedom in adjusting the frame rate to artistic needs, content, and display technology. In this paper, we solve this problem by proposing a novel filtering technique which enables emulating the whole spectrum of presentation frame rates on a single-frame-rate display. The key component of our technique is a set of simple yet powerful filters calibrated and evaluated in psychophysical experi-

1 Introduction

With the recent release of Peter Jackson's *Hobbit* trilogy in the HFR (high frame rate) format, another attempt was made to break with the almost century-old tradition of shooting films at 24 frames per second. It has been announced that Andy Serkis' *Animal Farm* and the sequels of James Cameron's *Avatar* will also employ high frame rates; thus, one can already talk about an emerging trend in film-making, which is backed by the presence of temporal up-sampling capabilities in most modern home entertainment systems. Increasing the acquisition and presentation frame rate helps to alleviate many artifacts of motion pictures, such as blur, strobing, flicker, or double edges, and thus leads to a more faithful image reproduction. These artifacts, however, contribute to the well-established aesthetics of the film, and the reactions of the audiences to the increased frame rate have been mixed so far. Many commentators contrast the classic

- Emulate different Frame Rates
- Frame Rate Maps
- Reduce Judder

Emulating displays with continuously varying frame rates (Templin et al.)

60 FPS

30 FPS

Locally Varying Frame Rates

Emulating displays with continuously varying frame rates (Templin et al.)

Still Frame

Velocities

Emulating displays with continuously varying frame rates (Templin et al.)

Still Frame

Frame Rate Map

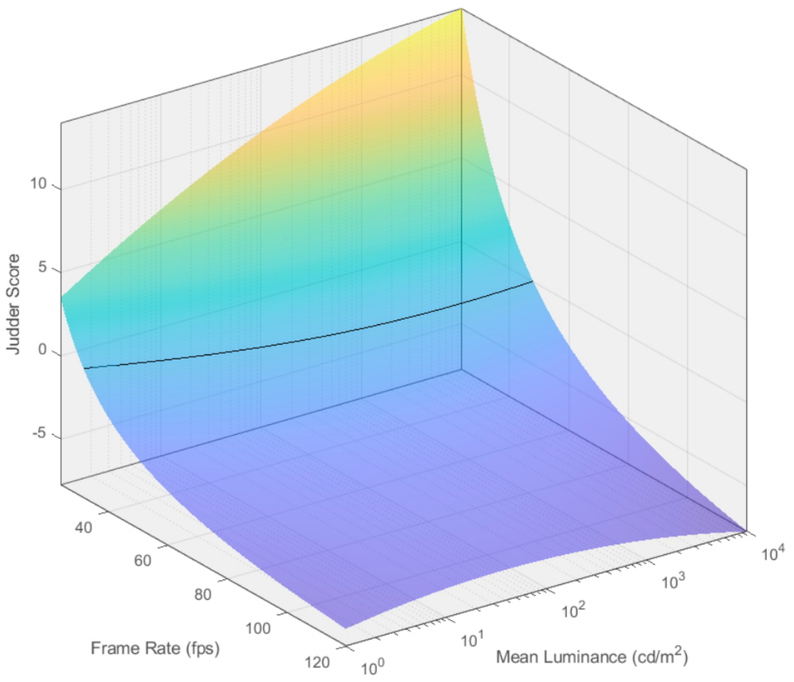
60 FPS

30 FPS

Research Question:

Can coherent judder based frame rate maps effectively reduce perceived judder in High-Dynamic-Range content and preserve a cinematic feel?

Our method



Frame Rate Map based on the Judder Score calculated for each image

Our method

Still Frame

Frame Rate Map
(50 - 25 FPS)

Our method

CHURCH

Judder Score:
7,6

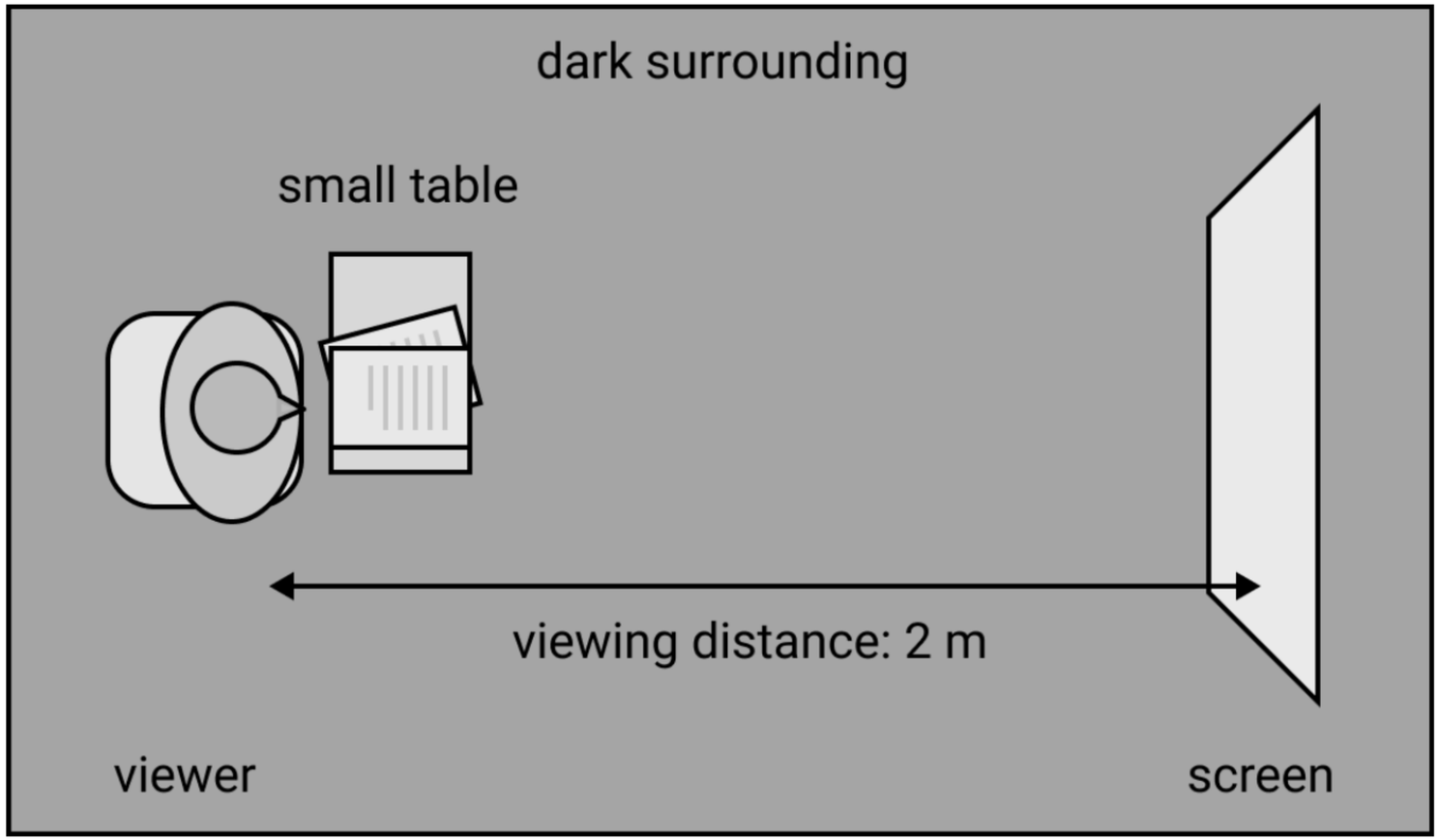
PIANO

Judder Score:
4,5

BARKEEPER

Judder Score:
9,6

Study Design



Three Sequences in Random Order:

- 50 FPS
- 25 FPS
- Chapiro
- Templin

Study Design based on the ITU-R BT.500

Study Design

No	Question	Scale/Category	
1	How did you perceive the **motion**	*choppy* to *smooth*	JUDDER
		annoying to *pleasant*	
2	Rate the **image quality** of the sequence.	*poor* to *excellent*	
3	How **cinematic** was the sequence?	*not cinematic* to *very cinematic*	CINEMATIC
4	Which **category** would you assign the sequence to?	*TV Show, TV Movie, Streaming Series, Cinema*	
5	What did you most **pay attention** to? (optional)	free text	
6	Comments and observations. (optional)	free text	

BARKEEPER

50 fps

25 fps

Chapiro

Templin

CHURCH

25 fps

Chapiro

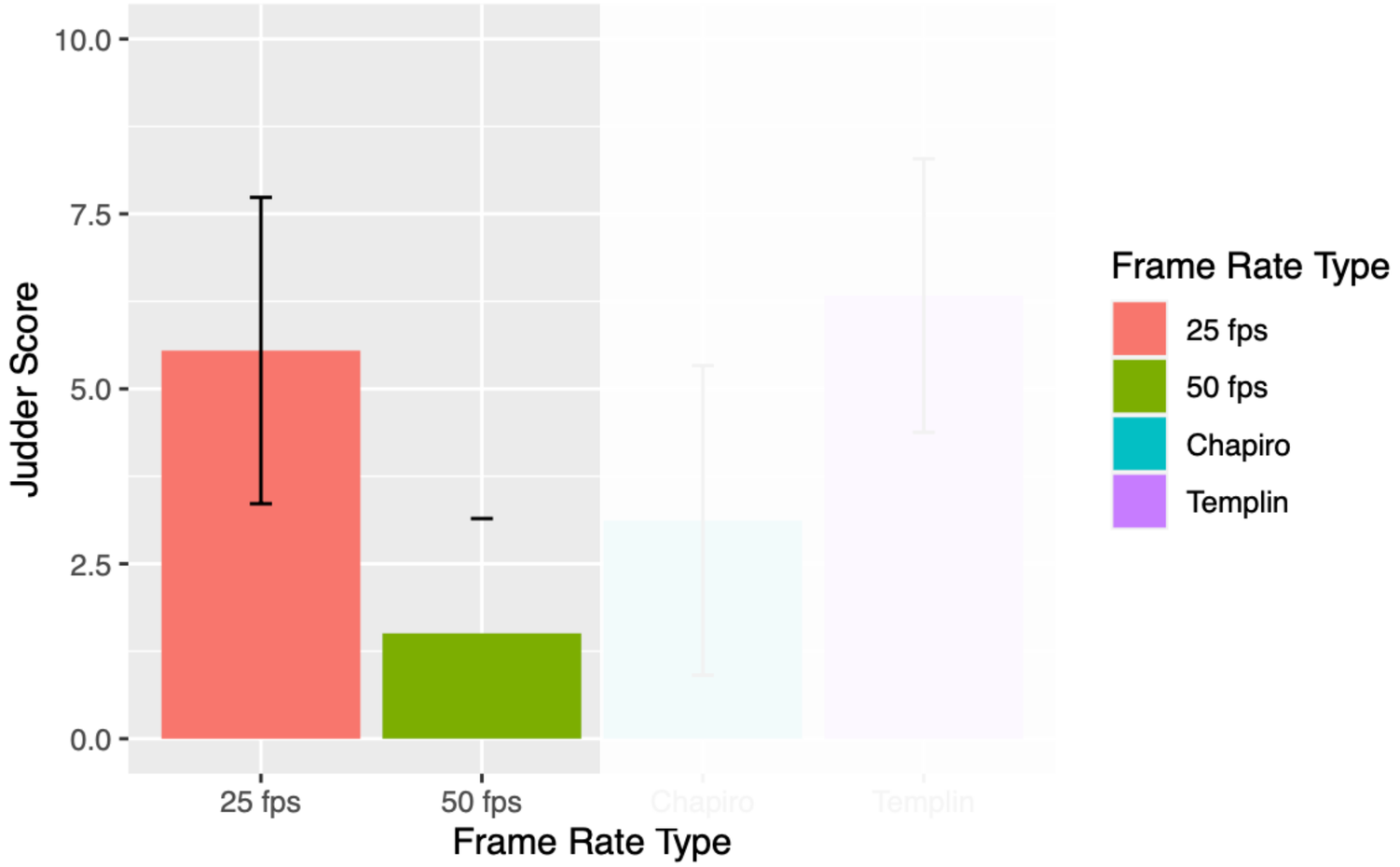
PIANO

25 fps

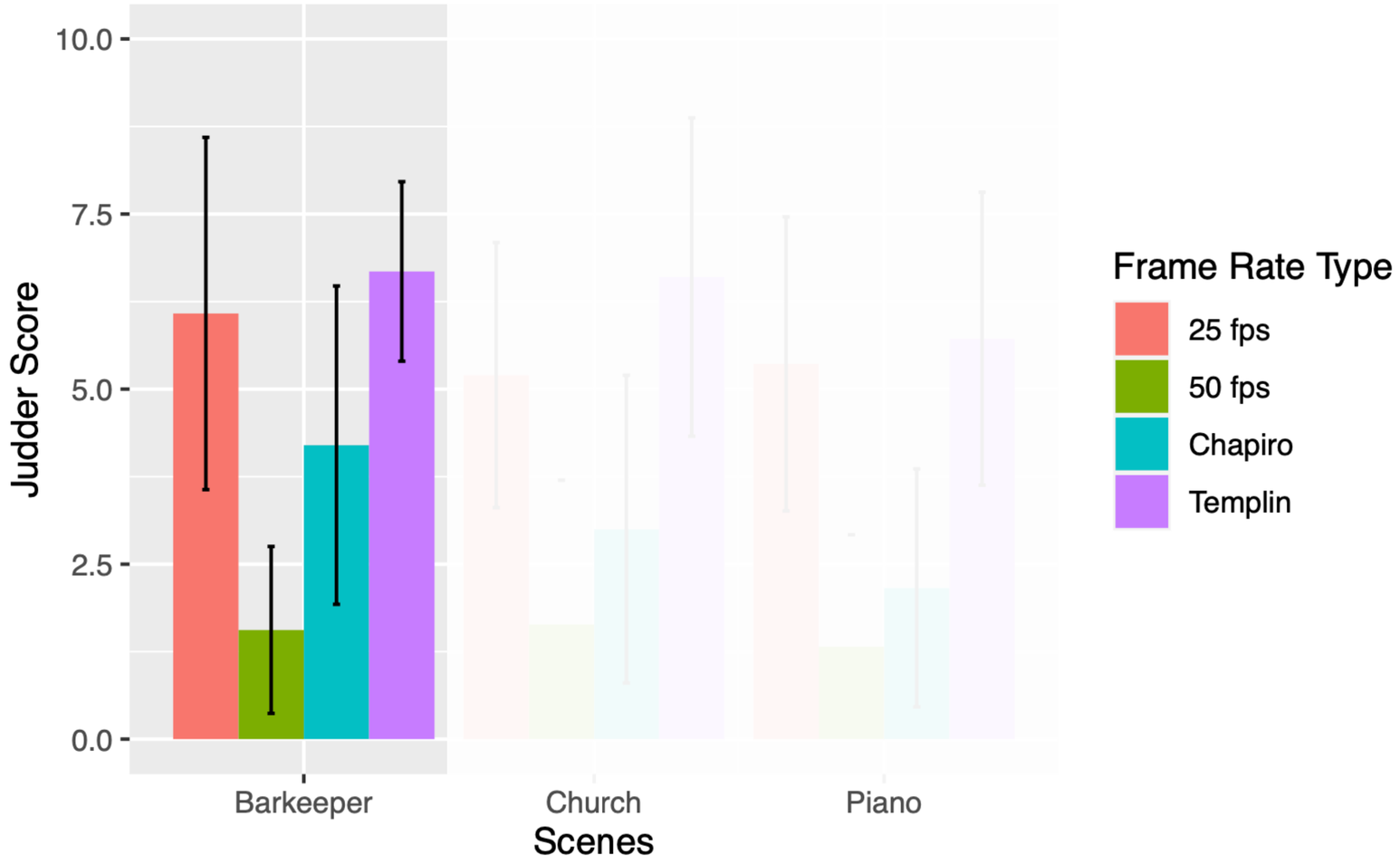
Chapiro

Results of the Study

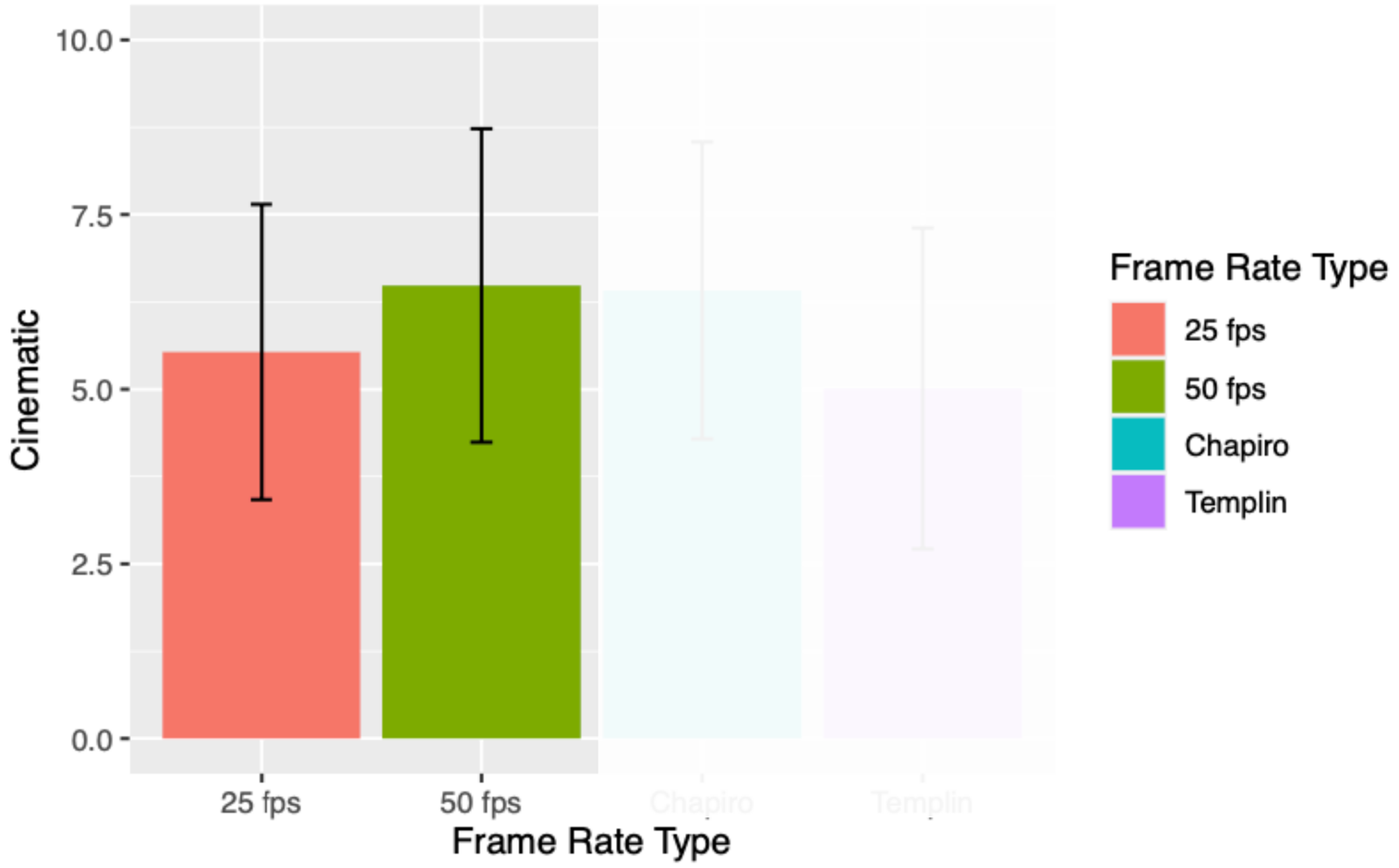
Where did the audience perceive ***judder***?



Where did the audience perceive ***judder***?



What did the audience experience as ***cinematic***?



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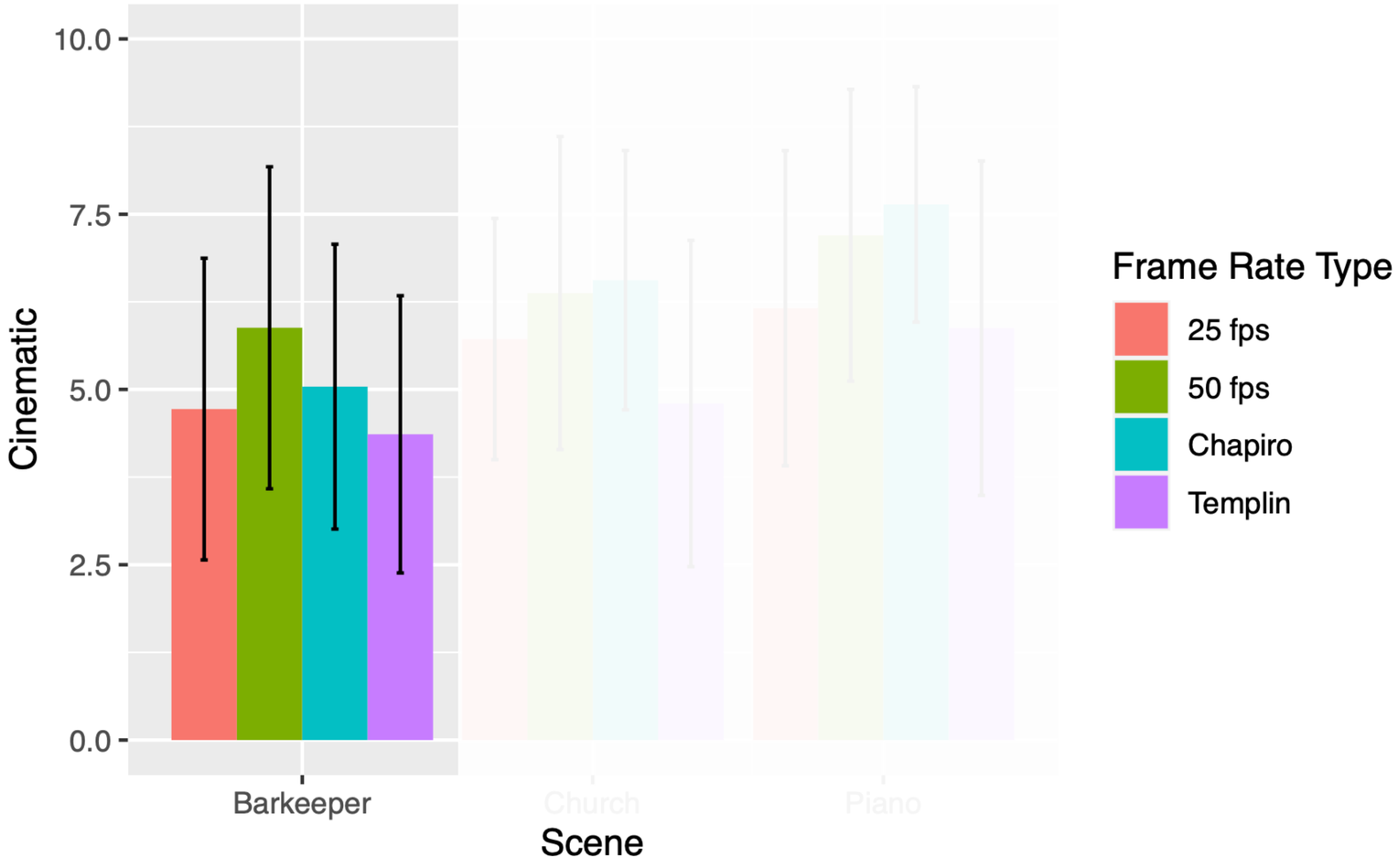

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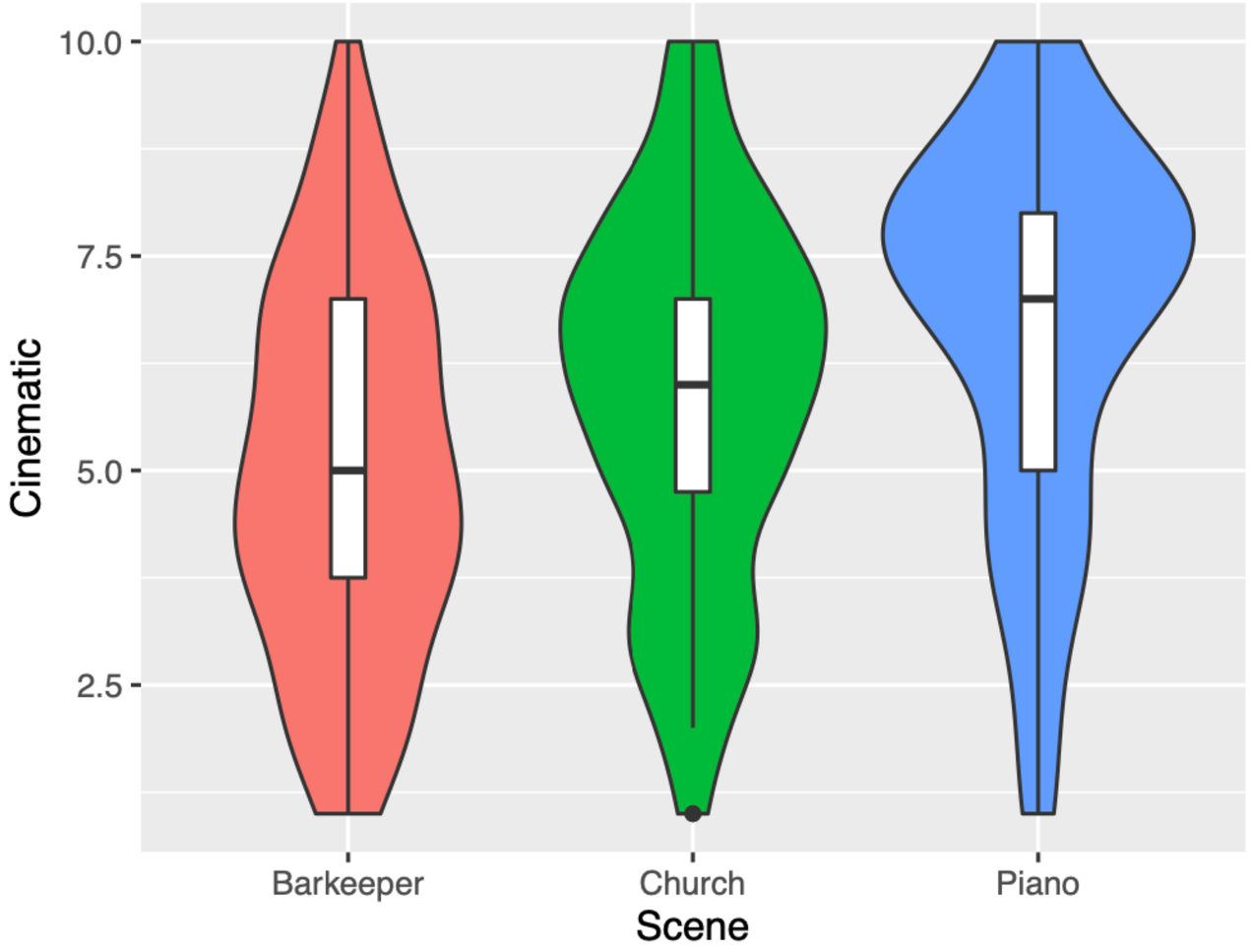

BARKEEPER

CHURCH

PIANO

Conclusion

Results

Thank you!