DiCE

Dichoptic Contrast Enhancement for VR and Stereo Displays

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realVision

Why is contrast important?

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High contrast

Low contrast

- *Colour richness*
- *Realism*
- *3D appearance*
- *Details*

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How to show high contrast in VR

HDR display

- *Cost*
- *Power*
- *Flicker*

Local tone-mapping operators

- *Computational cost*

Exploiting binocular vision

Idea

- *Use different views between the eyes to enhance image appearance*
- **Need to take care of Binocular Rivalry*

Related work

- *Binocular tone-mapping operators (BTMO): [Yang et al. 2012] [Zhang et al. 2018, 2019]*
- *Maximize image difference, yet maintaining viewing comfort*

Problems

- *Inconsistent enhancement*
- *Heuristic viewing comfort predictor*
- *Heavy optimization*

Left-eye image *Right-eye image*

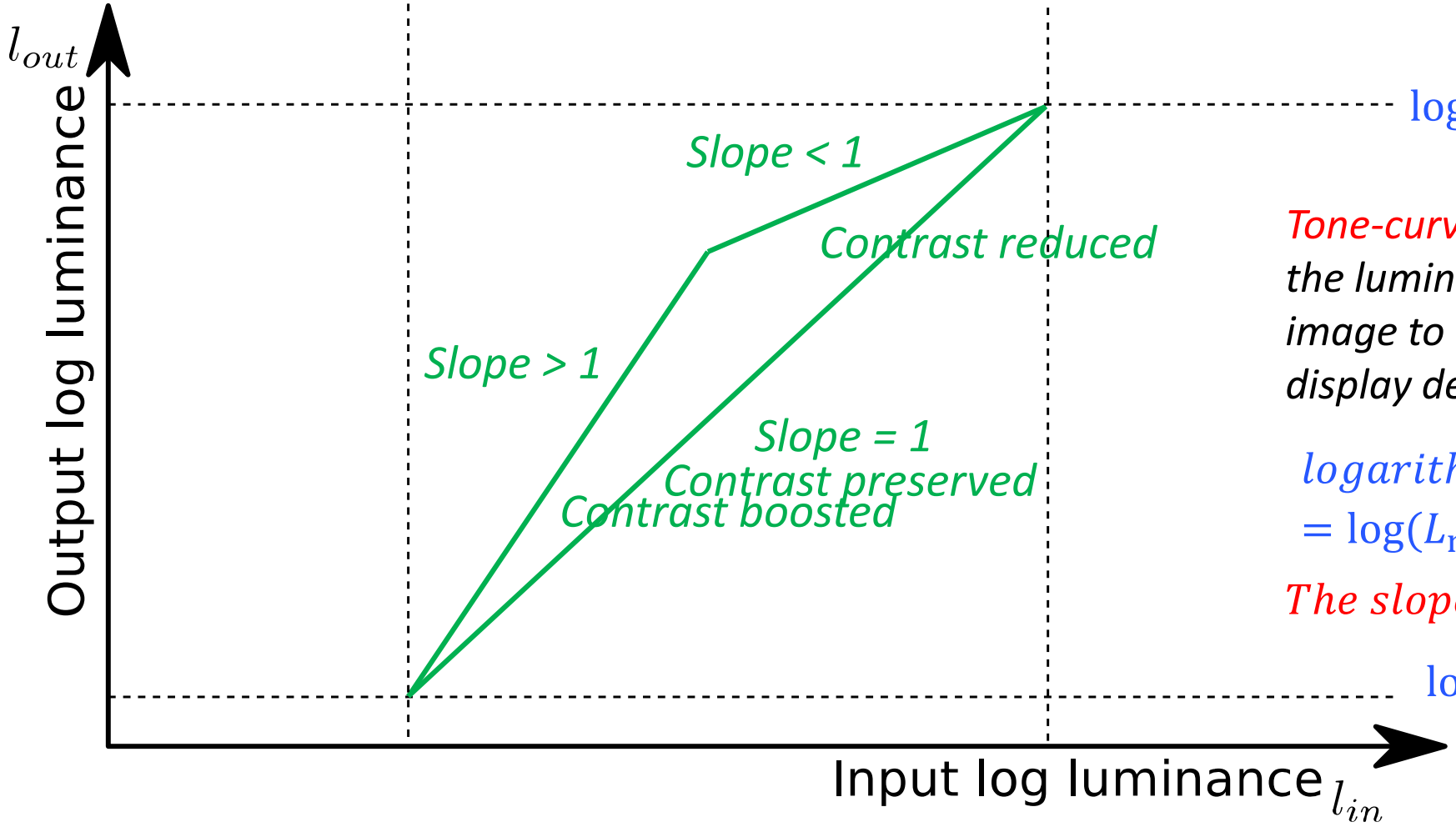
DiCE: Dichoptic* Contrast Enhancement

Left-eye Image

Right-eye Image

**Dichoptic presentation: two different images are presented to the two eyes*

Tone-curve and logarithmic contrast



Tone-curve a mapping from the luminance of the input image to the luminance of display device

$$logarithmic\ contrast = \log(L_{\max}) - \log(L_{\min})$$

The slope adjusts contrast

Cannot increase the contrast globally without a larger output dynamic range

Fusion of contrast

Contrast to the left eye *Contrast to the right eye*

$$C_m = \left(\frac{C_L^{\beta} + C_R^{\beta}}{2} \right)^{\frac{1}{\beta}}$$

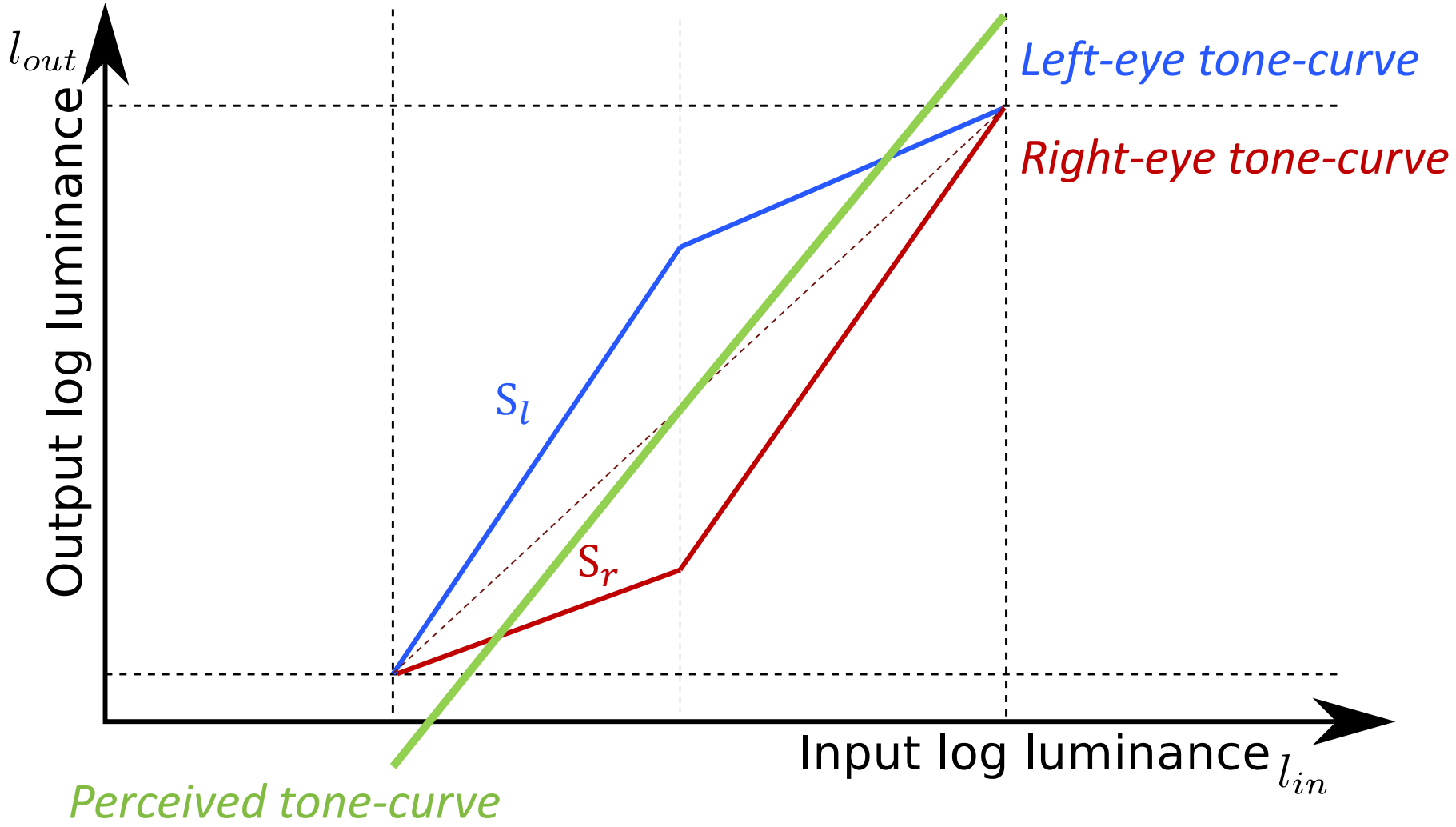
Perceived contrast

$$\beta \approx 3$$

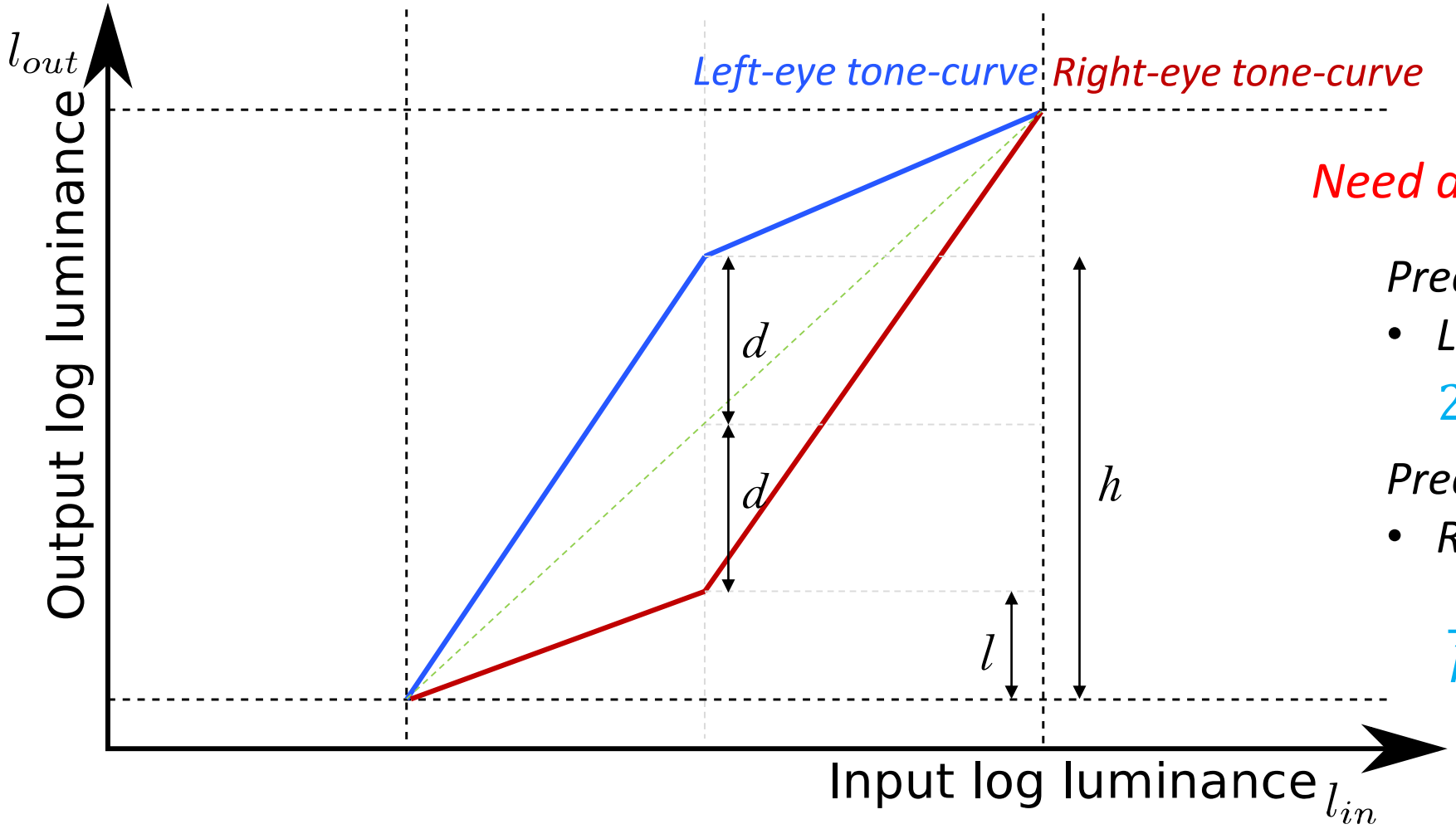
$$\Longrightarrow \quad C_m \geq \frac{C_L + C_R}{2}$$

[Legge & Rubin 1981]

Dichoptic tone-curves



Predictor of rivalry



Need a predictor of rivalry!

Predictor hypothesis 1

- *Luminance difference*

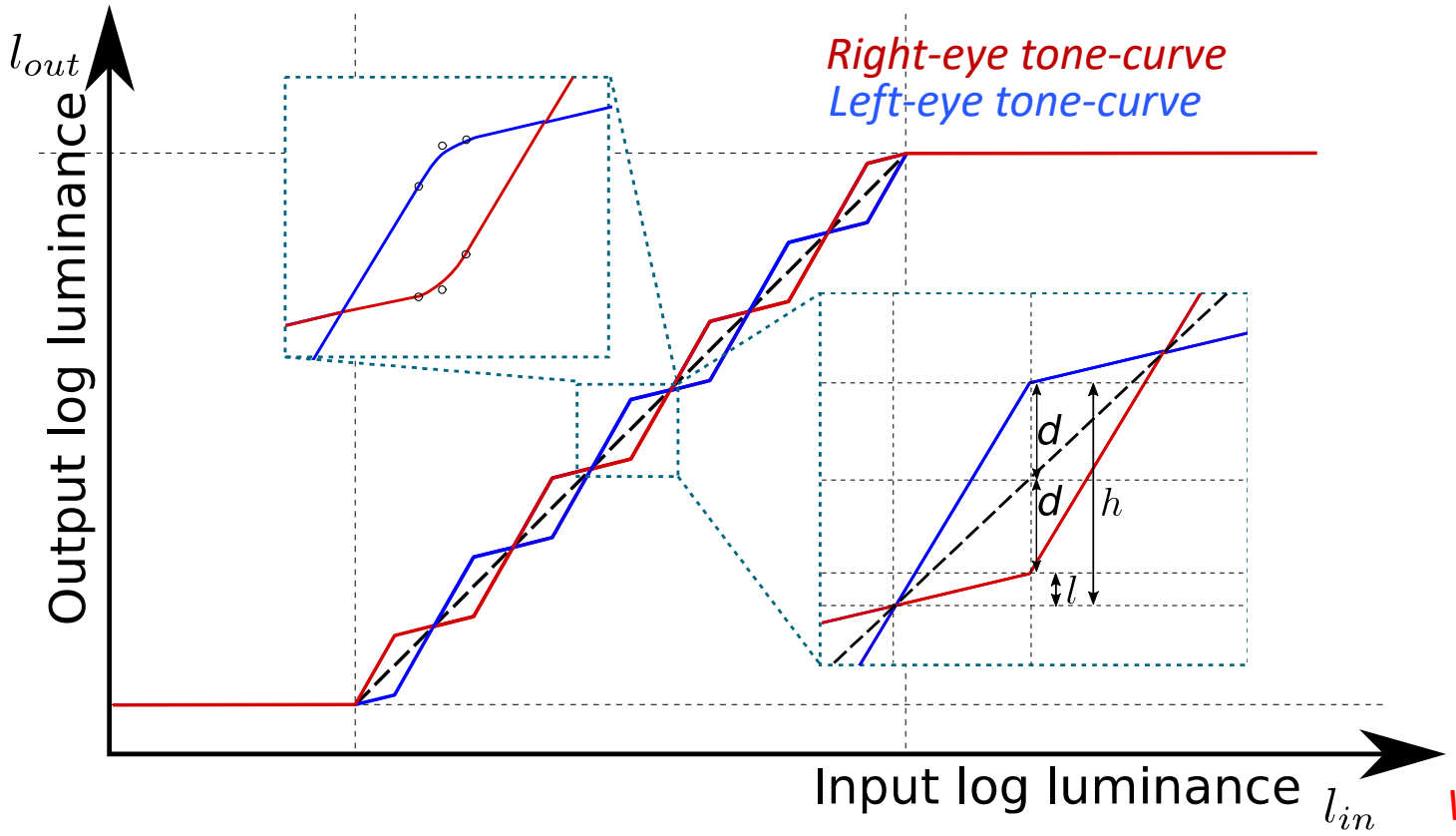
$2d$

Predictor hypothesis 2

- *Ratio of contrast*

$\frac{l}{h}$

Experiment 1 - Predictor of rivalry



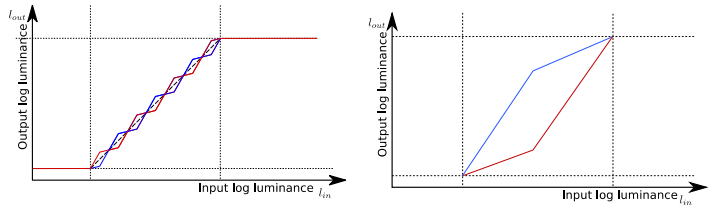
Interleaved tone-curve

Stimuli

- *16 binocular images processed by interleaved tone-curves*

Procedure

- *Adjust the difference d to find the strongest enhancement without rivalry (8 participants)*
- *Run the experiment for different number of linear segment N*

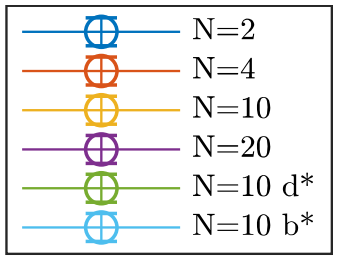


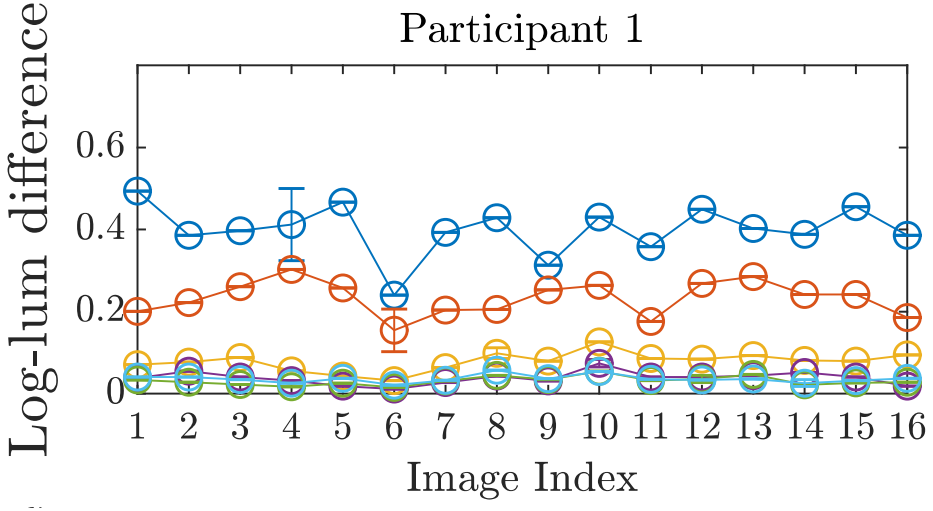
N=14 *N=2*

Which predictor is closer to a constant for different N?

Hypothesis 1	*Hypothesis 2*
Luminance difference	*Ratio of contrast*
$2d$	$\frac{l}{h}$

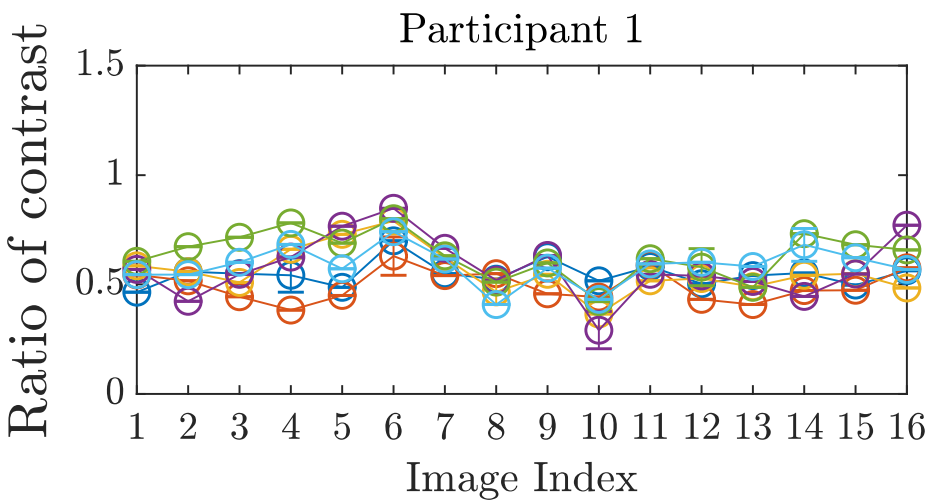
Experiment 1 - Predictor of rivalry





Hypothesis 1
Luminance difference

$2d$

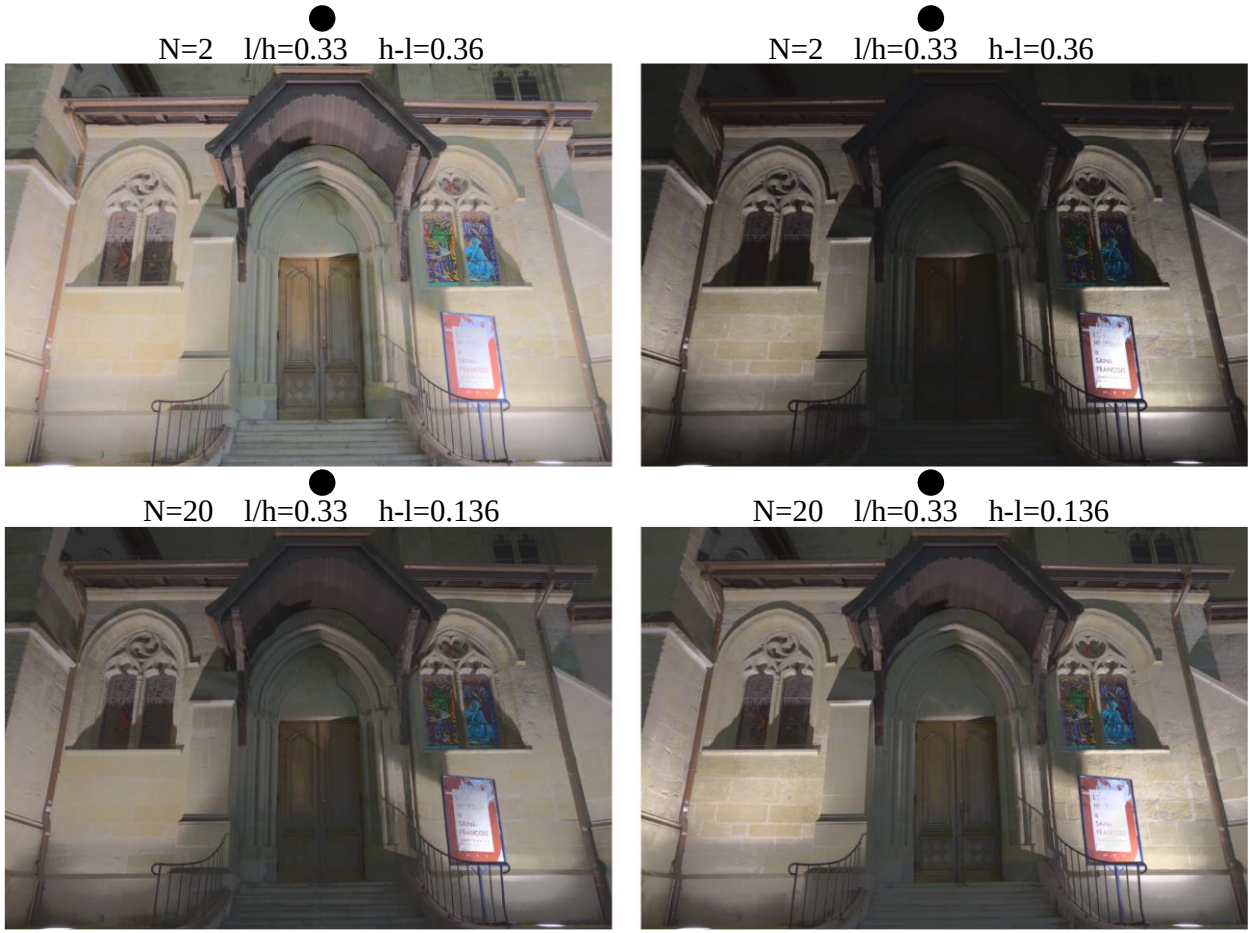


Hypothesis 2
Ratio of contrast

$\frac{l}{h}$

Better!

Selected examples

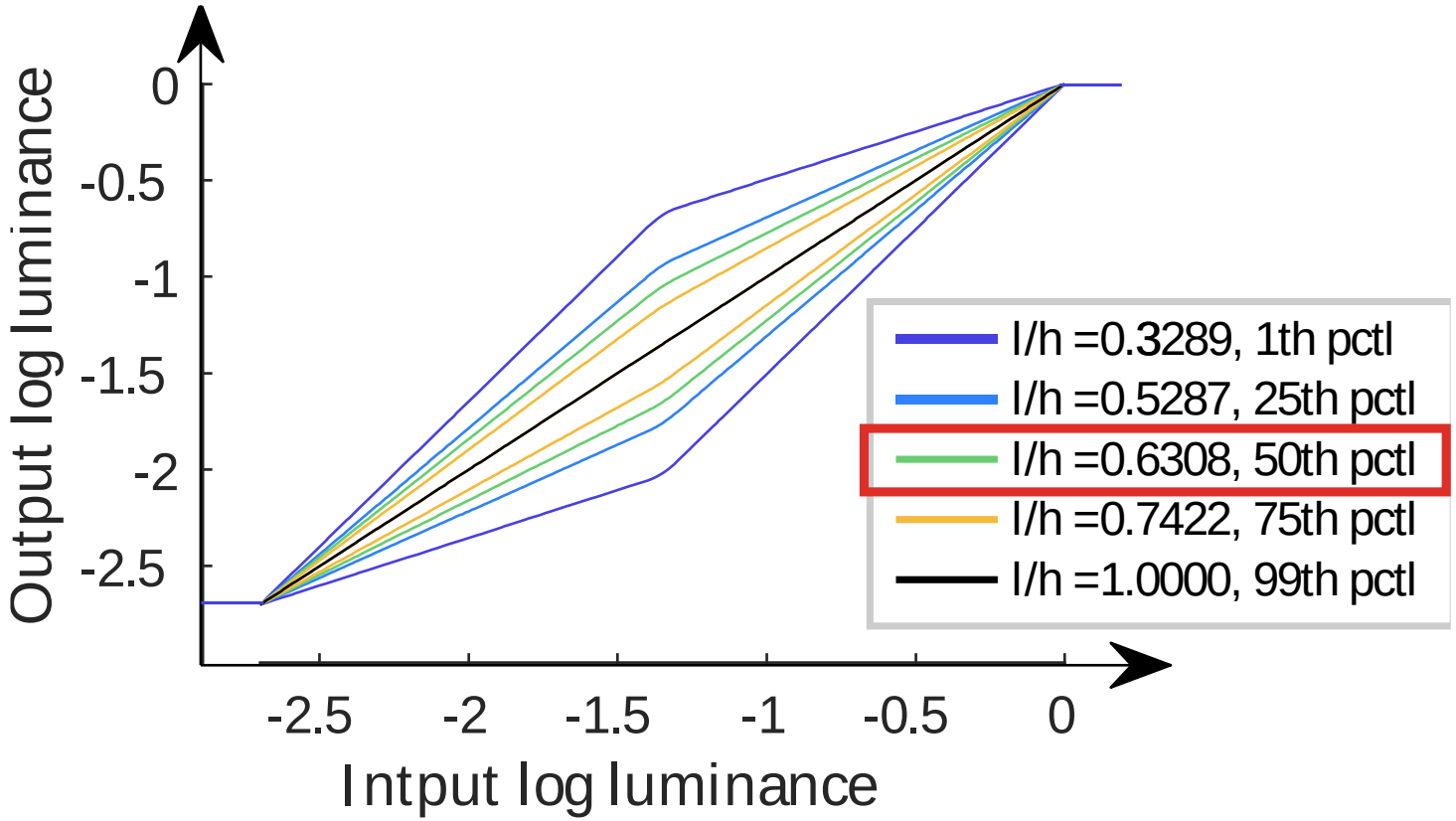


The two image pairs have the same ratio of contrast but different luminance difference

These images can be cross-fused with the assistance of the dots above

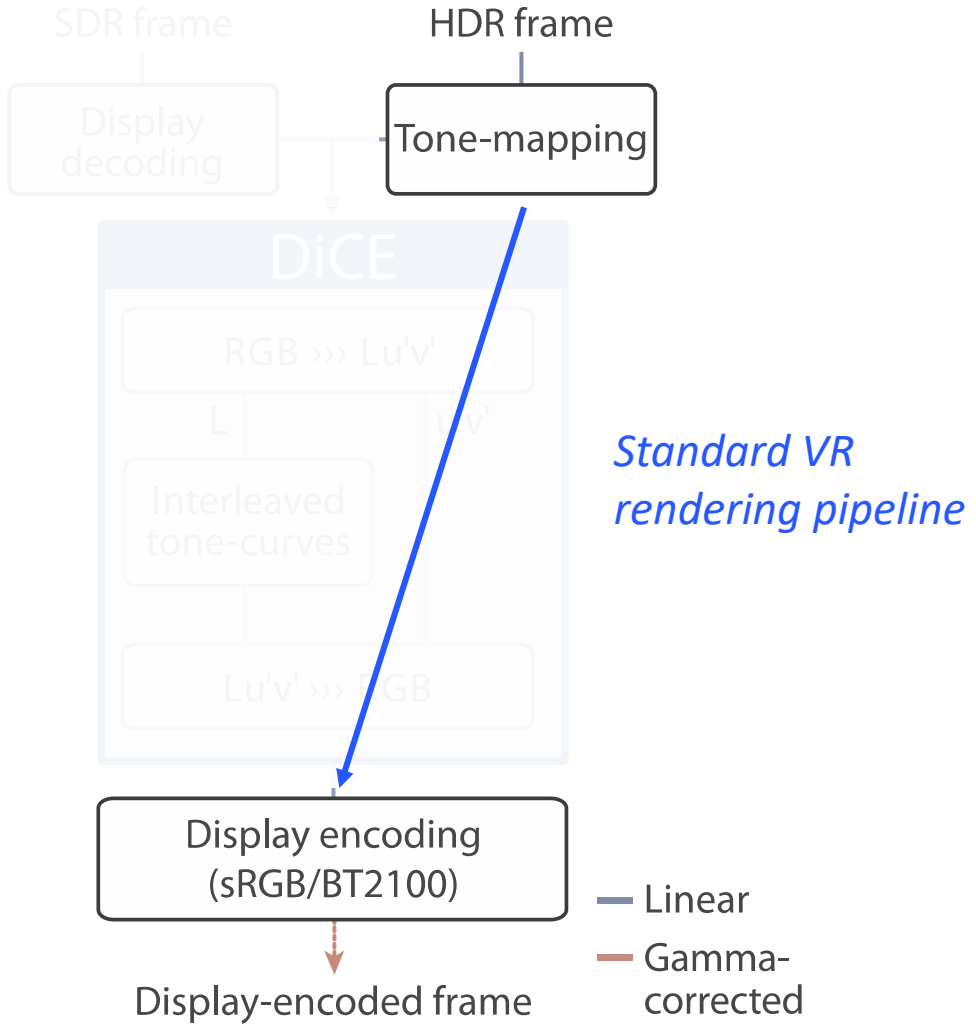
Final DiCE tone-curve

- *The shape of the DiCE dichoptic tone-curves for different ratios of contrast l/h*
- *Select the ratio that represents the 50th percentile of the data to shape the final tone-curve*



Integration of DiCE to the VR rendering pipeline

- *Seamless integration to any VR rendering pipeline*
- *Can take both HDR and SDR images as input*
- *Negligible computational cost*

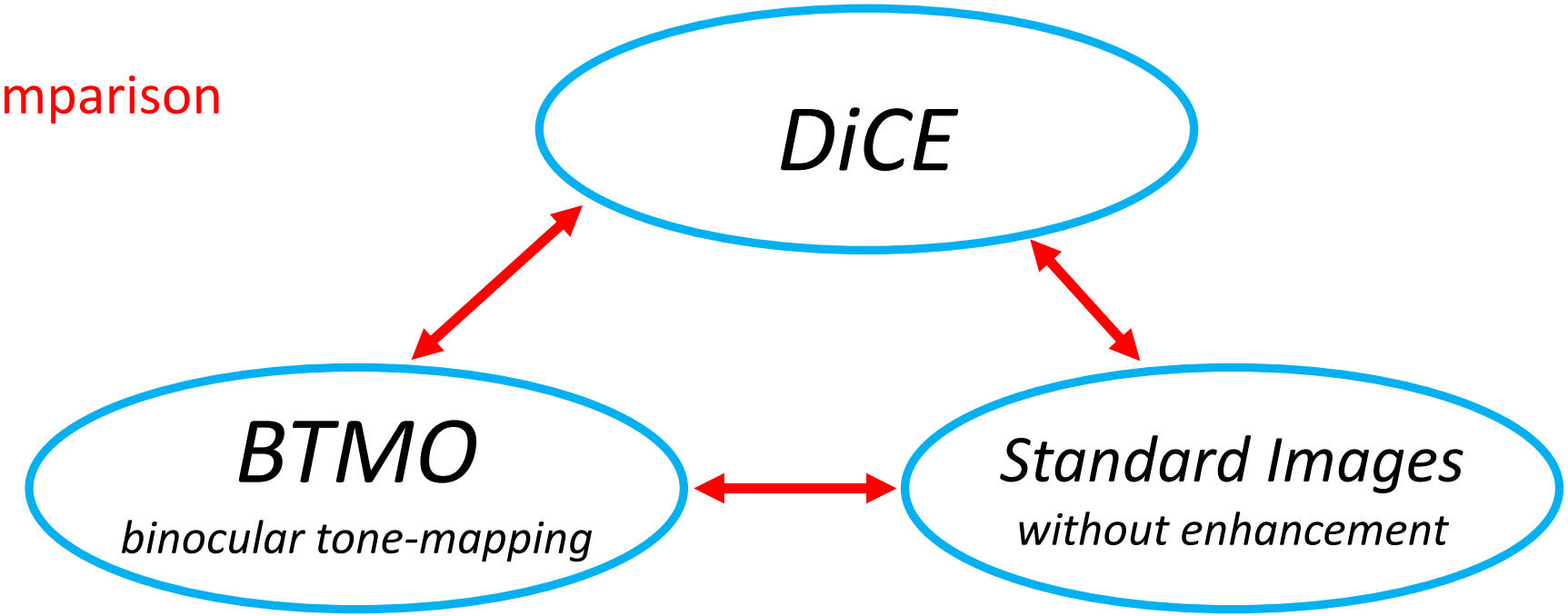


Experiment 2 – Validation

Pairwise Comparison

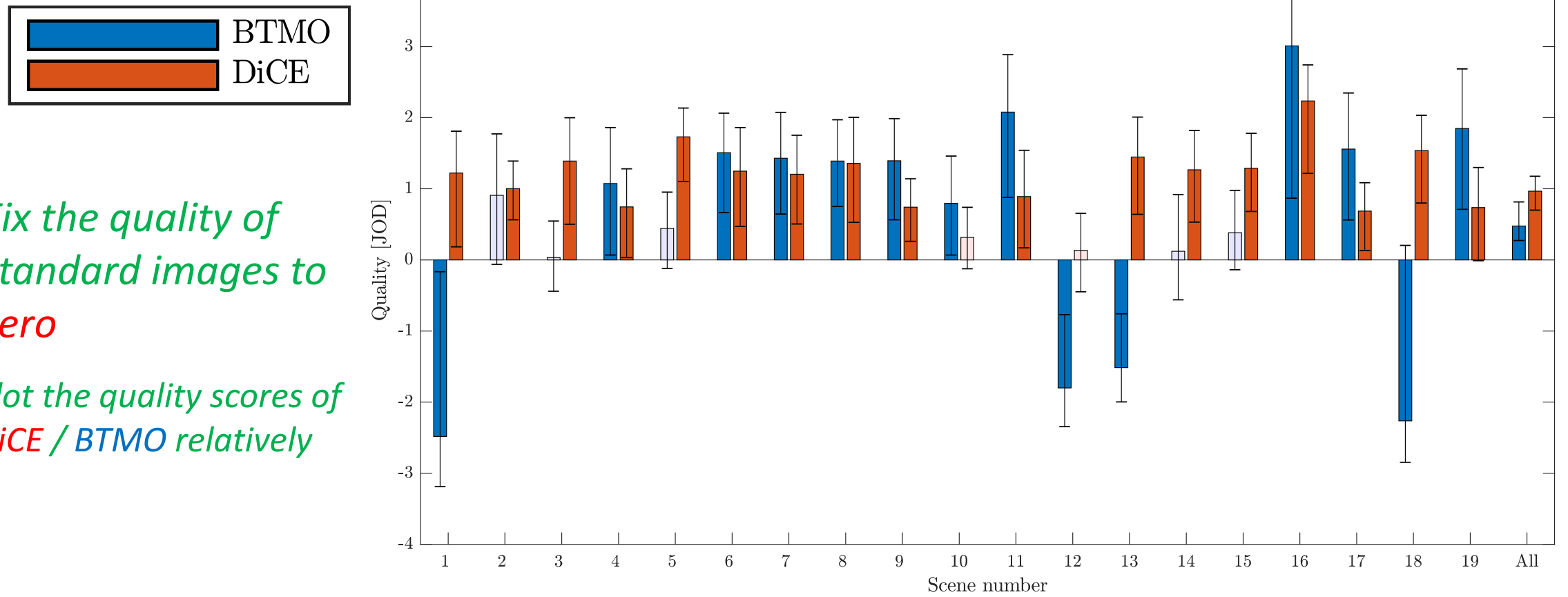
Contrast

Preference



Run comparisons for 19 scenes (16 participants)

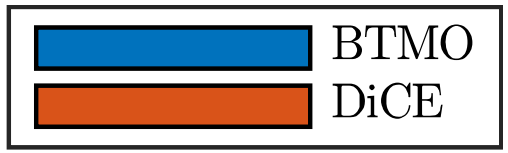
Experiment 2 – Validation (Contrast Perception)



Fix the quality of standard images to zero

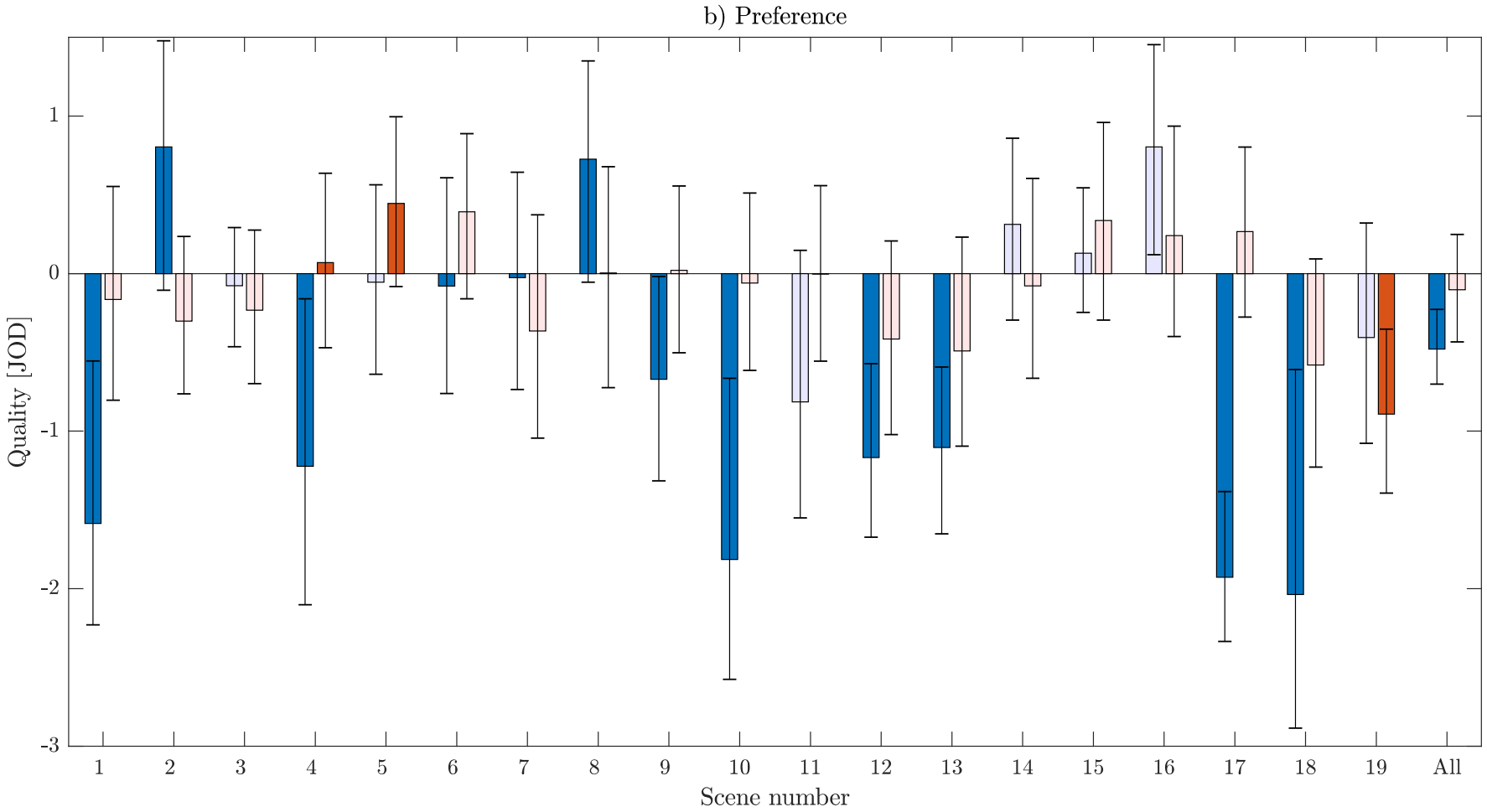
Plot the quality scores of DiCE / BTMO relatively

Experiment 2 – Validation (Overall Preference)



Fix the quality of standard images to zero

Plot the quality scores of DiCE / BTMO relatively



Summary

Contributions:

- *Explicit contrast enhancement based on established psychophysical models.*
- *A simple yet effective rivalry predictor based on new experimental findings.*
- *Easy integration to any VR rendering pipeline with any choice of tone-mapping operators.*
- *Negligible computational cost, processing an image pair in milliseconds without GPU acceleration.*

Limitations:

- *Inherent trade-off between contrast enhancement and binocular rivalry.*

THANK YOU!

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Project URL (Unity Asset available)
https://www.cl.cam.ac.uk/research/rainbow/projects/dice/

QR code

DiCE demo available in the session break




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