Comparison of Recent Flicker Metrics in Variable Refresh Rate Displays

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August 22, 2025

iMiD 2025
BEYOND PIXELS, BEYOND LIMITS

Link to this presentation: https://cutt.ly/imid25_vrr_flicker

Overview

- Background & motivation
- VRR Flicker Metrics
- Subjective study
- Metrics correlation results

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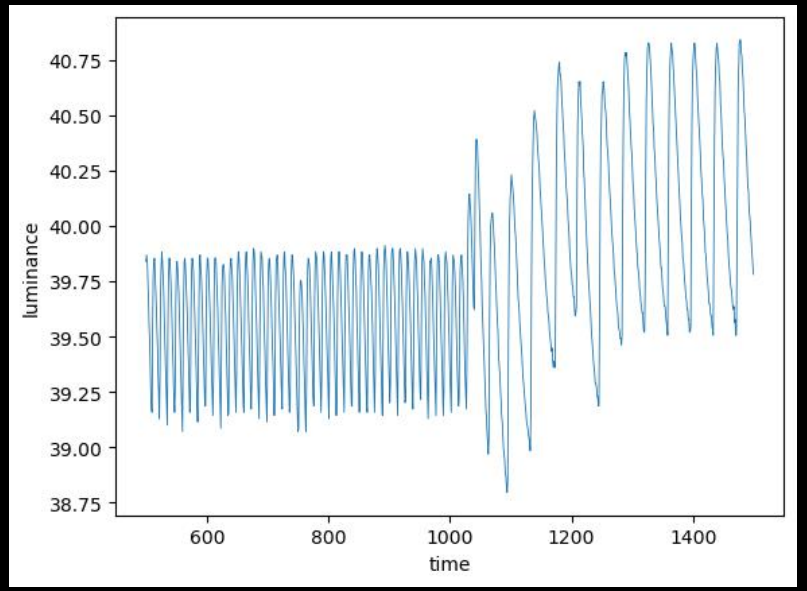
Background

What is flicker?

"perception of visual unsteadiness induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a static observer in a static environment"[1]

VRR flickering?

Visible flickering caused by change in frame rate, often resulting in transient changes to luminance.



1. *CIE TN 012*. (2021).

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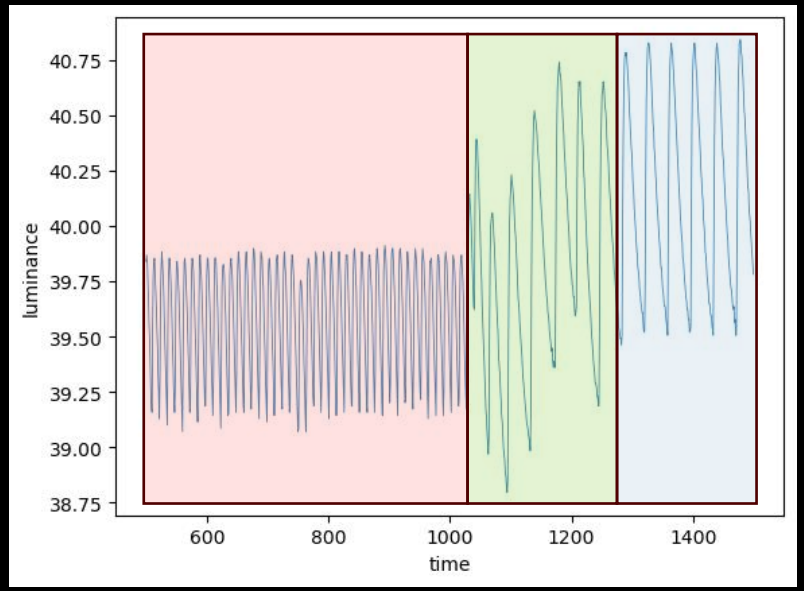

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Background

Variable refresh rate (VRR) displays

- adjust V-Blank to support range of refresh rates
- Market names: AdaptiveSync, MediaSync, G-Sync, FreeSync, ProMotion, Q-Sync[1]
- Increasingly common use case:
  - (2019) Over 91% of gaming monitor supports VRR[2]
  - Power saving – limit refresh rate during low power
  - Expanding uses in mobile and AR/VR

1. Copyright and trademark of VESA, Nvidia, AMD, Apple and Qualcomm respectively
2. Source: https://levvvel.com/gaming-monitor-study/

Motivation

- **JEITA (IEC 61747-30-1) used for VRR flicker**
  - Works OK for fixed refresh rate – display / lighting
  - Fails for VRR display (will show later)

- **Fallback – depends on subjective evaluation**
  - Hard to reproduce
  - Costly
  - Too late

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- **Need a better solution:**
  - Objective
  - Correlate to human perception
  - Open standard (ICDM: Temporal Measurements)

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Recent advancements in VRR Flicker metrics

- Konica Minolta (VRRF)
- Admesy (AFM)
- Samsung Display (D.Flicker)

Konica Minolta (VRRF)

- **Generate TCSF in time domain**
  - From IEC62341-6-3
  - Convert to time domain IRF using IFFT
  - Phase recovery per IDMS
- **Convolution of input waveform & IRF**
- **(Max-Min) / Average**

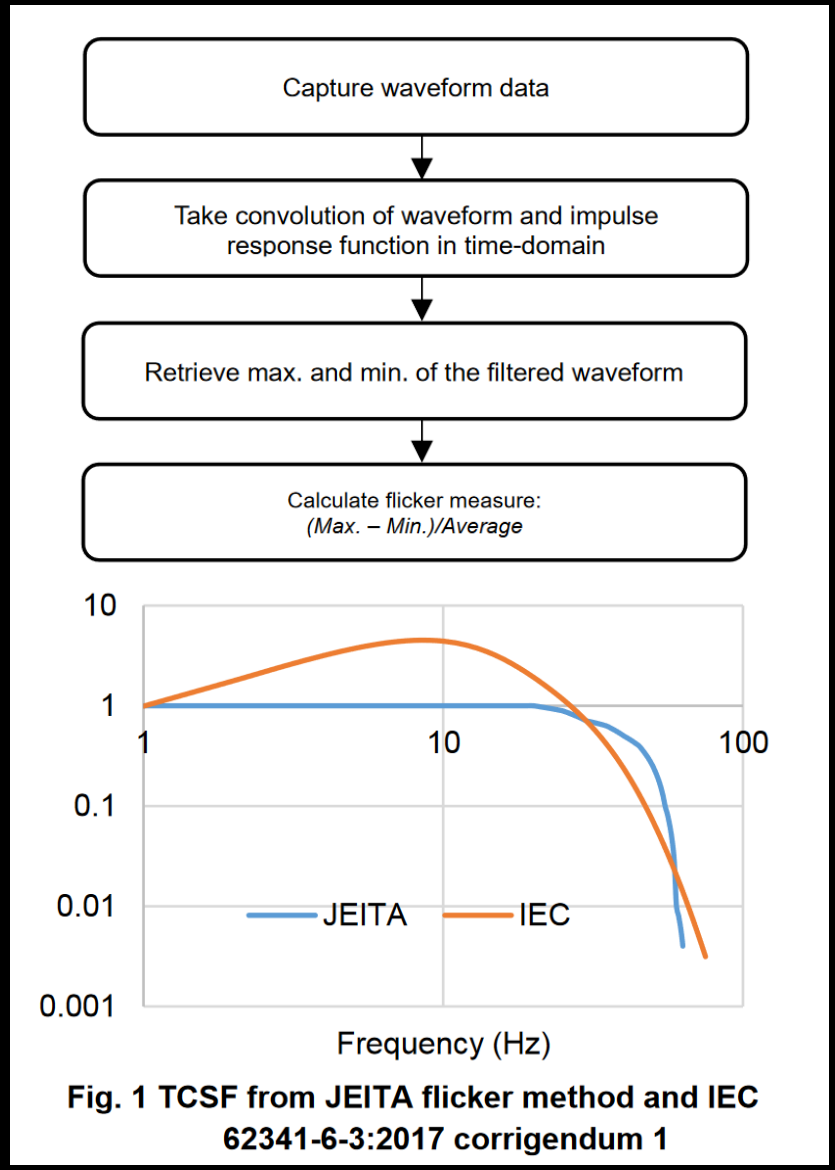
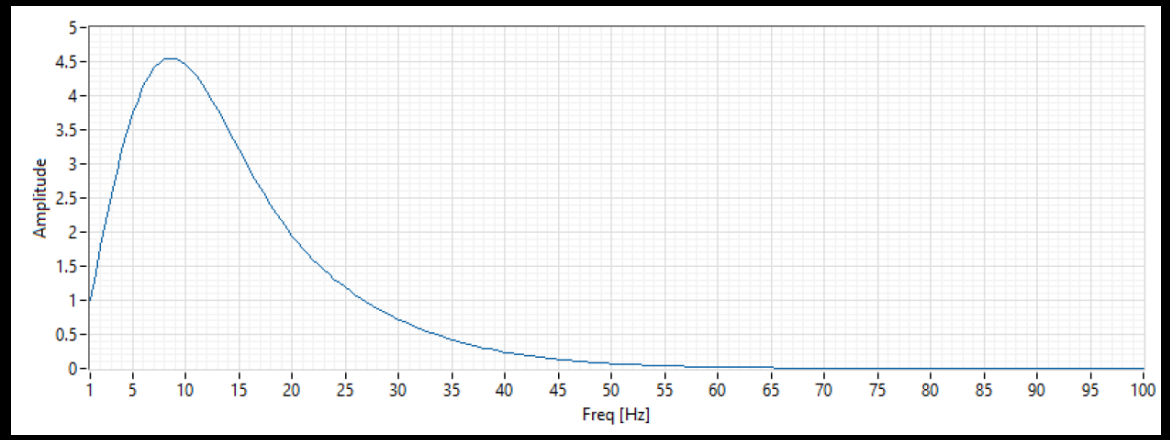


Fig. 1 TCSF from JEITA flicker method and IEC 62341-6-3:2017 corrigendum 1

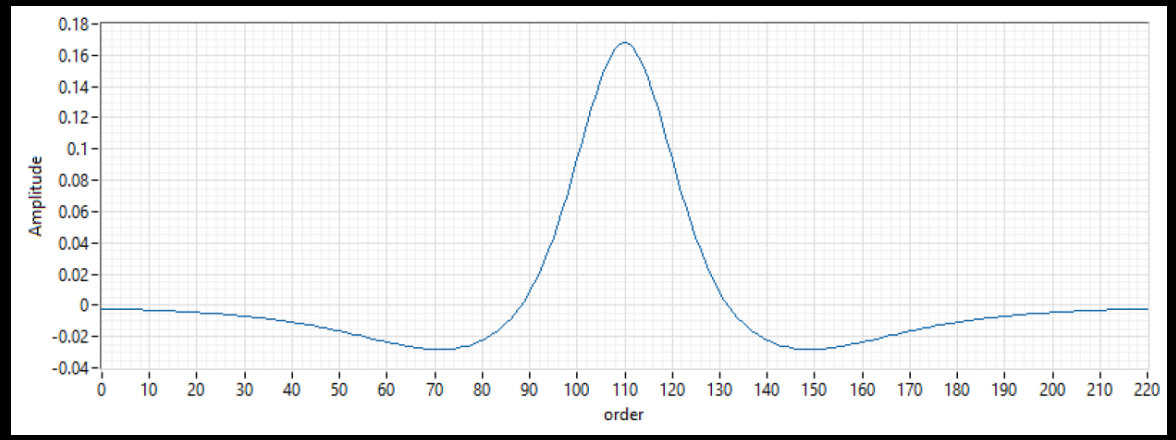
source: Masuda, Uematsu, and Maeda, "Flicker Calculation Method for Variable Refresh Rate Display."
TCSF – Temporal Contrast Sensitivity Function
IRF – Impulse Response Function
IFFT – Inverse Fourier Transform

Admesy (AFM)

- **Generate TCSF in time domain**
  - From IEC62341-6-3
  - Convert using FIR filter via equiripple method
- **Convolution of input waveform & IRF**
- **(Max-Min) / Average**



TCSF (Freq domain)



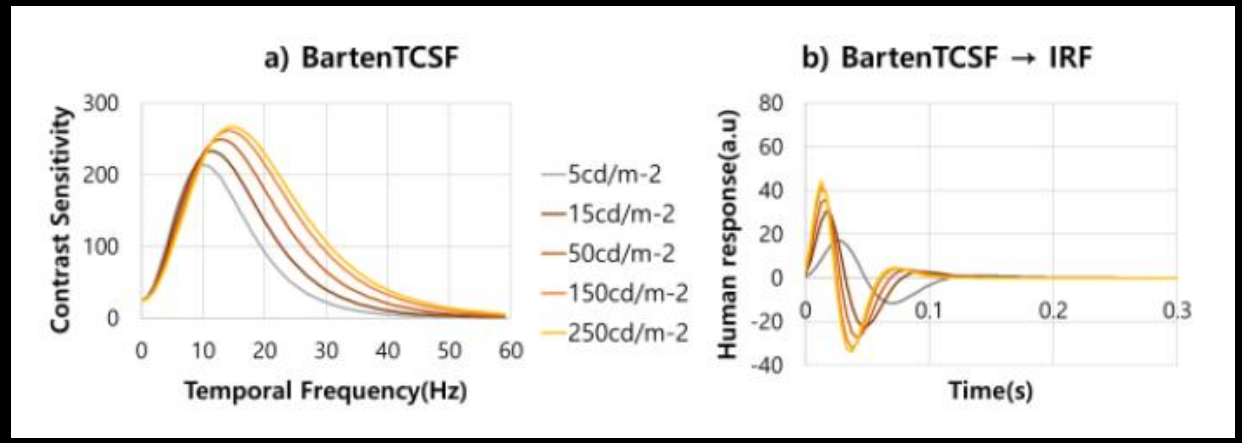
TCSF FIR Filter

source: Admesy, “IEC62341 Afm Frequency versus Time Resolved Flicker.”

Samsung Display (D.Flicker)

- **Generate TCSF in time domain**
  - From BartenCSF curves -- based on condition, such as luminance and size.
  - Convert to time-based IRF using Kramers-Kröning relations to recover phase
- **Convolution of input waveform & IRF**
- **RMS value of filtered signal, normalized by peak luminance**

Causality is preserved
Similar to human vision system, viewer only respond to events after they occur.



Source: Kim, Hwang, and Yeom, “Time-Domain Analysis for Variable-Refresh-Rate Display Flicker”; Kim et al., “Enhancing VRR Flicker Index Using Time-Domain Analysis.”

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UBC subjective study

THE UNIVERSITY OF BRITISH COLUMBIA

Generate Mean Opinion Score (MOS) under various driving condition on multiple VRR displays (VA, IPS, WOLED, QD-OLED)

- **Subject sample size (n): 30**
  - Male (18) and female (20)
  - Age 20 - 65

MOS Rating	Definition
No (4)	Not visible
Mild (3)	Only slightly visible after extended staring at screen
Moderate (2)	Slightly visible at first glance
Severe (1)	Clearly visible; annoying

- **Capture condition**
  - LMD: Admesy Asteria
  - Sampling frequency: 3kHz
  - # samples: 6000

Follows ITU BT.500 recommendations

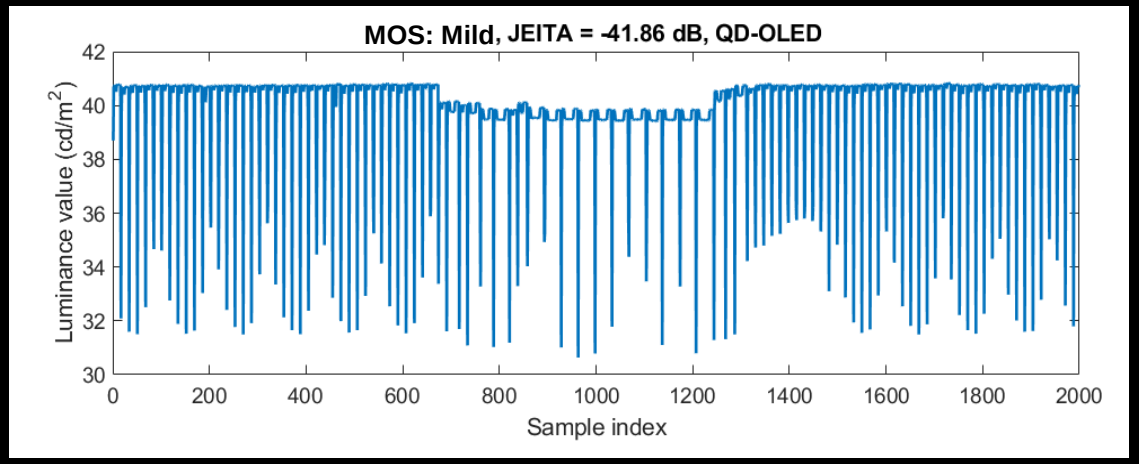
Tohidypour, Seto, and Nasiopoulos, “A Comprehensive VRR Dataset of Luminance Signals and Their Perceived Flicker Levels: Insights for Display and GPU Manufacturers.” Paper submitted for publication.

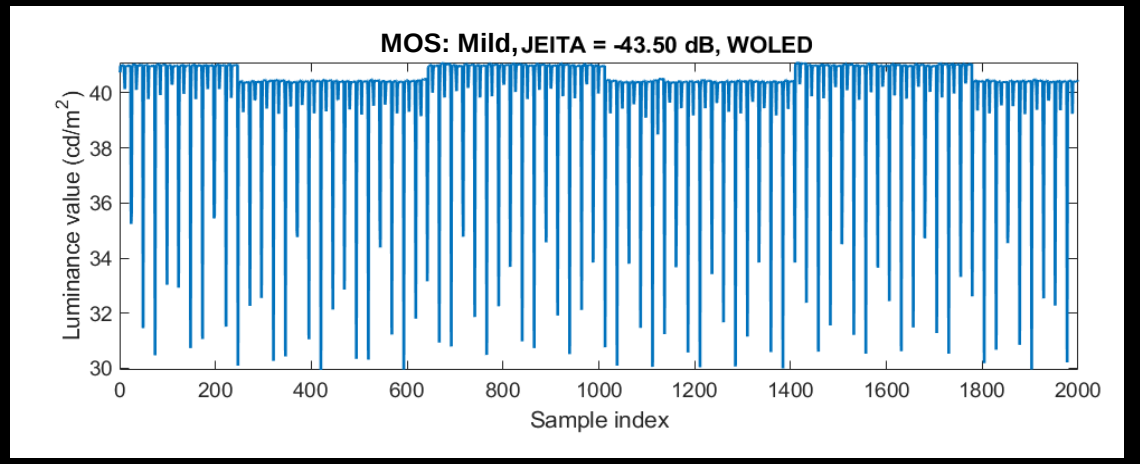
UBC subjective study

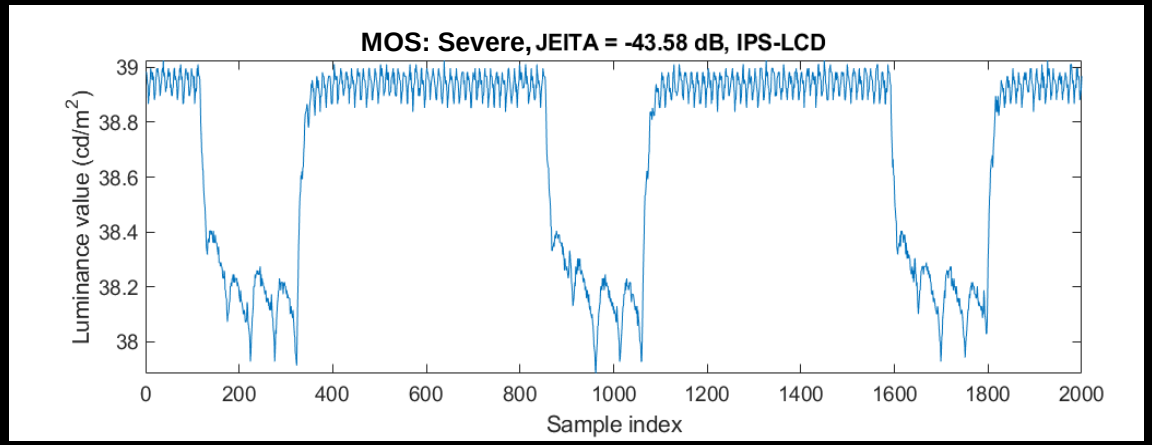
Tech	Size	Source	Min/Max supported refresh rate (Hz)
VA LCD	27″	RTX 2080 Ti GPU	60-240
IPS LCD	27″	RTX 2080 Ti GPU	50-240
QD-OLED	34″	RTX 4080 GPU	60-175
WOLED	42″	RTX 4080 GPU	24-120

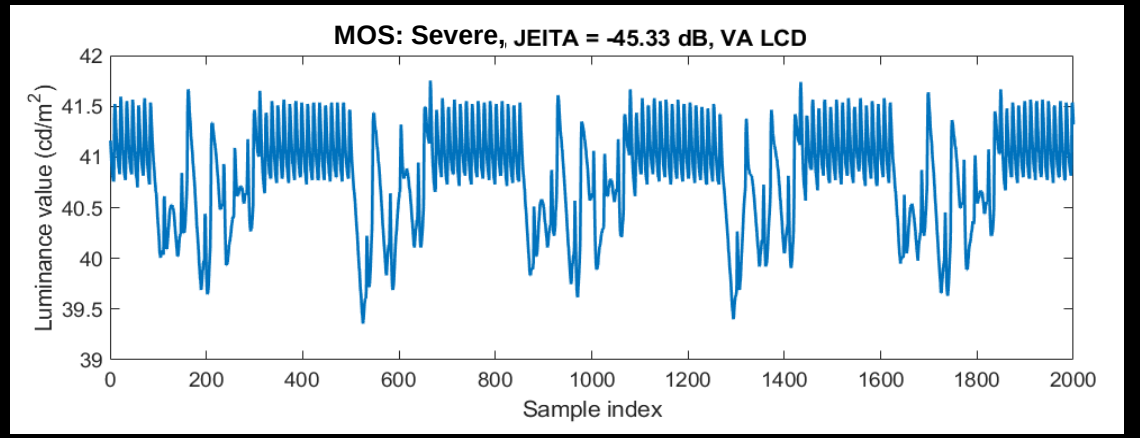
UBC subjective study

- Examples of captures and JEITA failures









UBC subjective study

Dataset evaluation

- **Intra-Class Correlation Coefficient (ICC) to assess individual agreement & average ratings across all raters.**
  - **ICC(2,1): 0.719** (95% CI, $p < 0.001$) – good agreement among individual raters.
  - **ICC(2,k): 0.987** (95% CI) – near-perfect consistency of mean scores.

  Raters had a shared understanding of the 4-point scale and applied it consistently.

Metric evaluation

- **Spearman ranking correlation measures the strength and direction of monotonic, but not necessarily linear, relationship. (closer to 1 is better)**

- **Pearson coefficient of correlation measures the strength and direction of linear relationship. (closer to 1 is better)**

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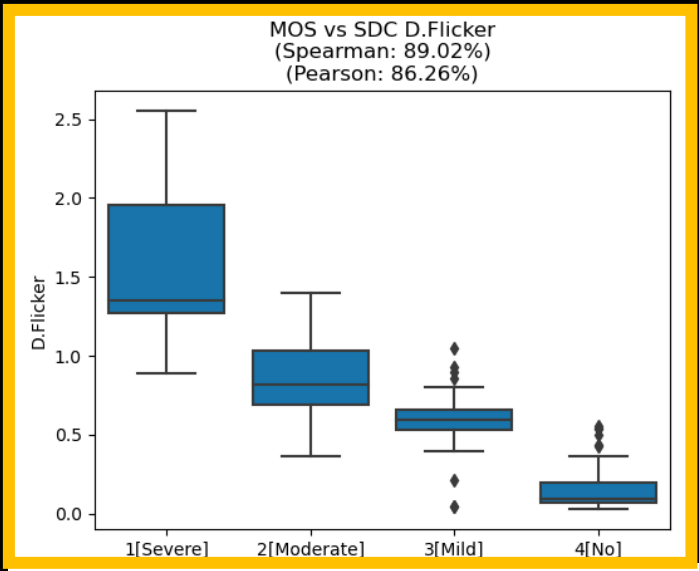
Result



	JEITA	VRRF	AFM	D.Flicker
Spearman	71.91%	72.34%	80.77%	89.02%
Pearson	71.88%	74.15%	74.52%	86.26%

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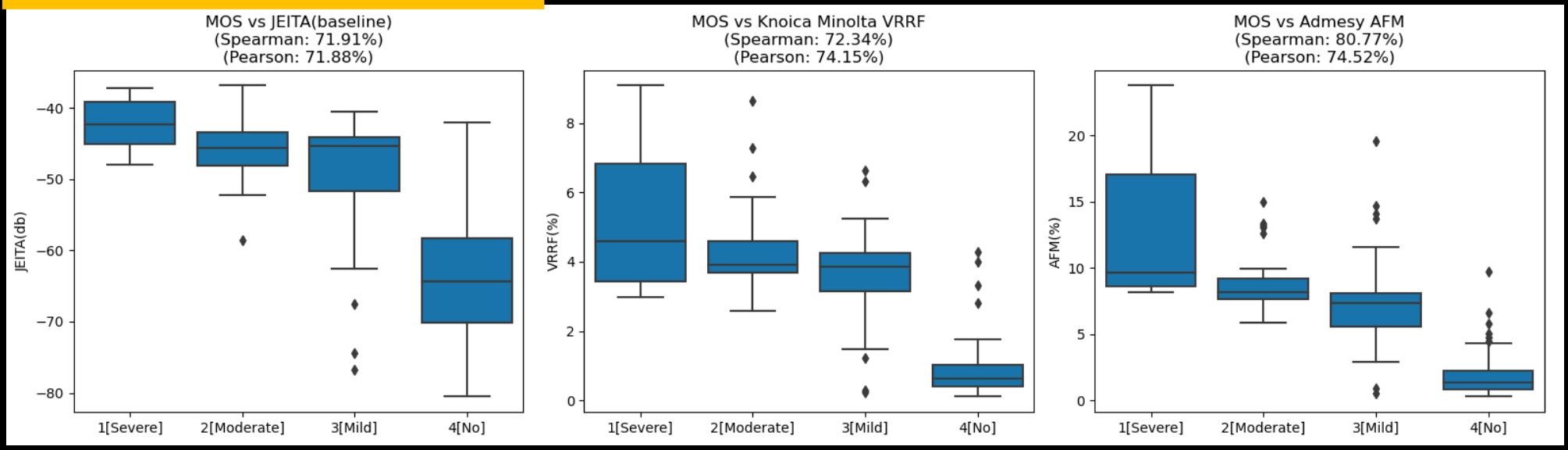

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- **Survey of recent metric for VRR flicker**
- **Subjective evaluation dataset for VRR flicker**
- **Our contributions:**
  - Result of recent VRR metrics correlation results with human perception

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D. Flicker outperforms other metrics compared.