

# 60 MS TO GET IT RIGHT GAZE-CONTINGENT RENDERING & HUMAN PERCEPTION

Dr. Rachel Albert, GTC San Jose 2019

# **GOAL: IMMERSIVE VR**

Requirements to mimic real-world human visual experience

- Wide color gamut / high dynamic range
- High frame rate, Low latency
- Wide Field of View (FoV)
- High spatial resolution

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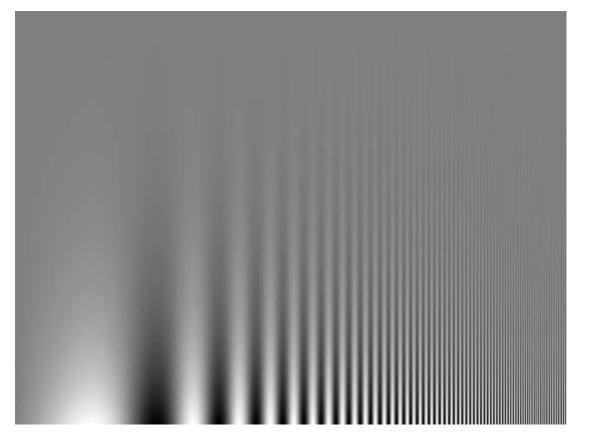
- Wide color gamut / high dynamic range
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- Wide Field of View (FoV)
- High spatial resolution

Computation Cost Bandwidth

Power/Heat/Weight

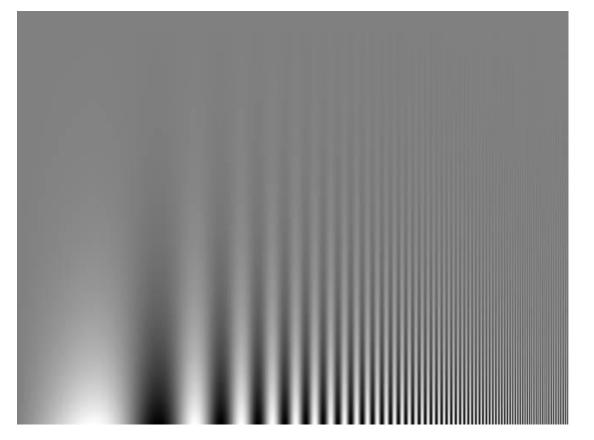
## HUMAN VISUAL PERCEPTION IS LIMITED

**Detection Threshold** 

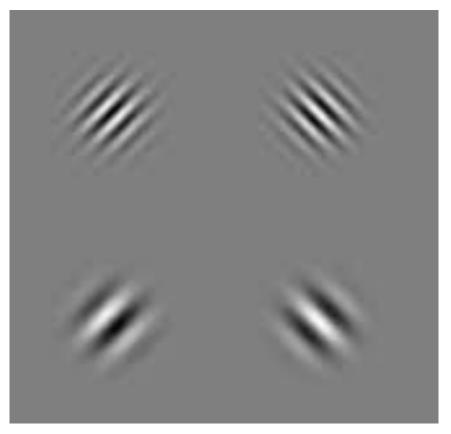


## HUMAN VISUAL PERCEPTION IS LIMITED

#### Detection Threshold



#### **Resolution Threshold**



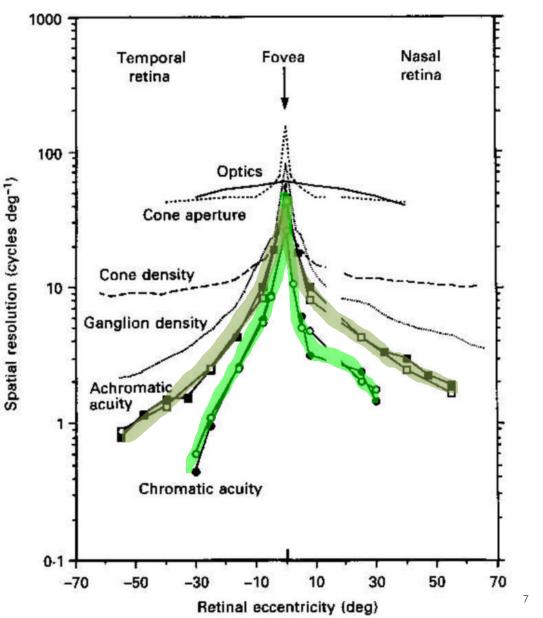
# HUMAN VISUAL PERCEPTION IS NON-UNIFORM

Resolvable spatial resolution decreases in the periphery as a function of eccentricity.

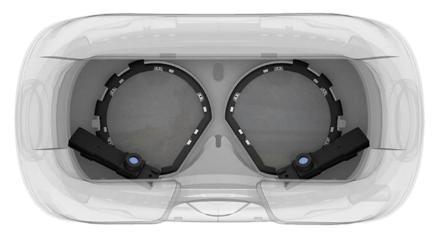
Figure from Anderson et al. 1991

Achromatic Acuity

📁 Chromatic Acuity



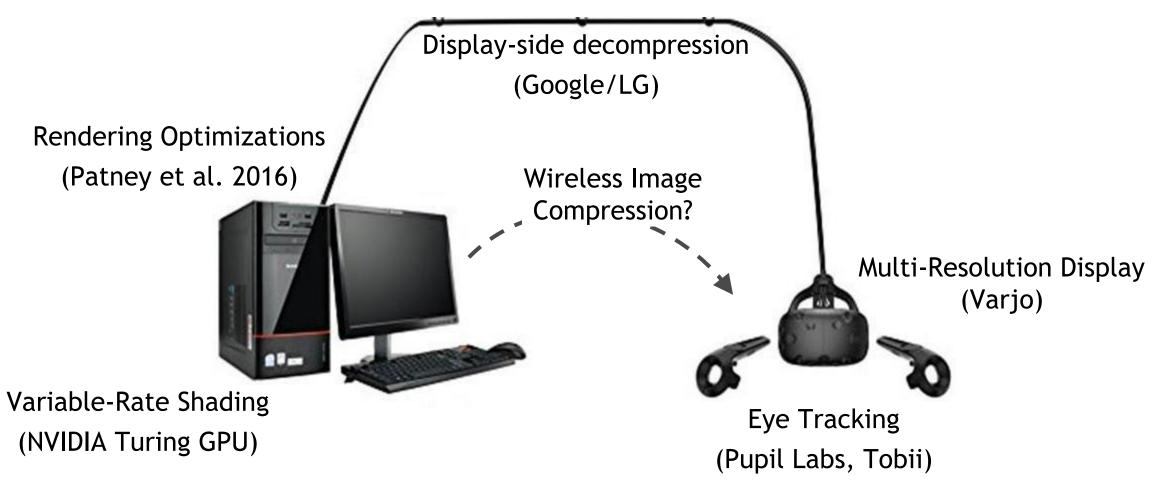
## ONE SOLUTION: GAZE-CONTINGENT IMAGERY







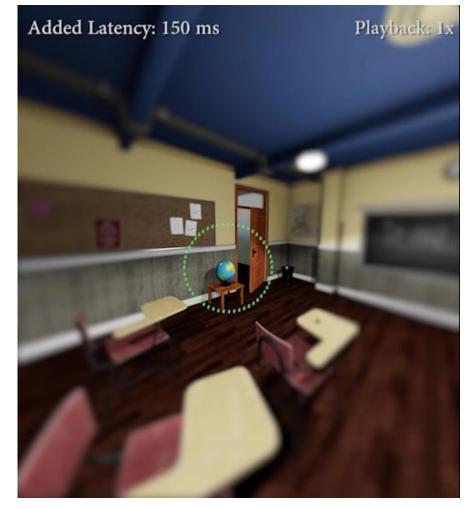
## SYSTEM REQUIREMENTS FOR GAZE-CONTINGENT RENDERING



## SACCADIC EYE MOVEMENTS & SACCADIC OMISSION

- During a saccade, the eye moves at 500 deg/sec
- Latency may cause the peripheral image to be visible
- BUT, Saccadic omission blocks perception of this image

How long is the omission period for rendered scenes?



## EXPERIMENT: LATENCY REQUIREMENTS FOR GAZE-CONTINGENT RENDERING

- Eye tracking latency only
- Free viewing, 4 seconds per trial
- Task: Yes/No Response
   "Did you see any artifacts?"
- Amount of peripheral degradation varied based on response 1 up/ 1 down adaptive staircase

# **EXPERIMENTAL DESIGN**

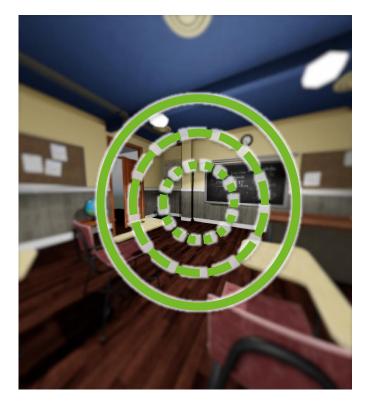
Fovea Size Full-Resolution Area 5°, 10°, 20° Ecc.

#### **Foveation Technique**

Peripheral Rendering Method Subsampling, Gaussian, fCPS

#### Eye-Tracking Latency

Added Latency 0, 10, 20, 40, 80, 150 ms

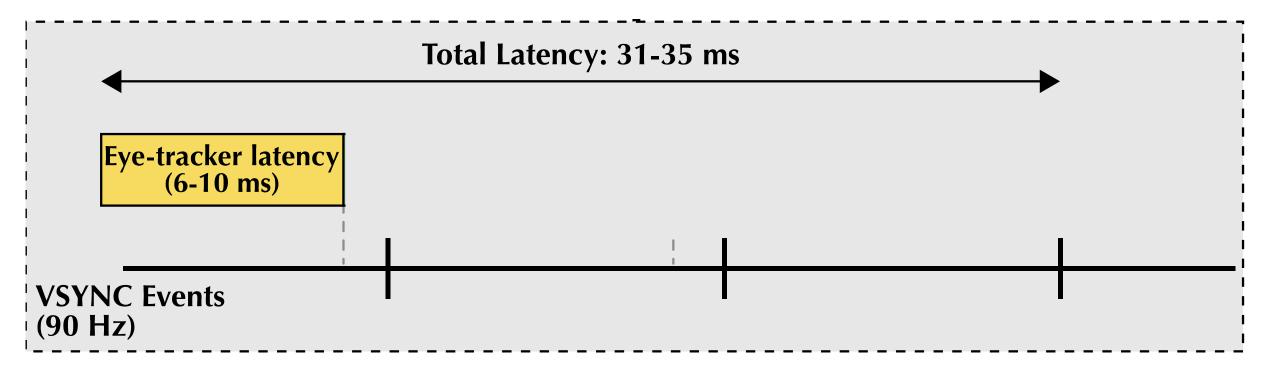




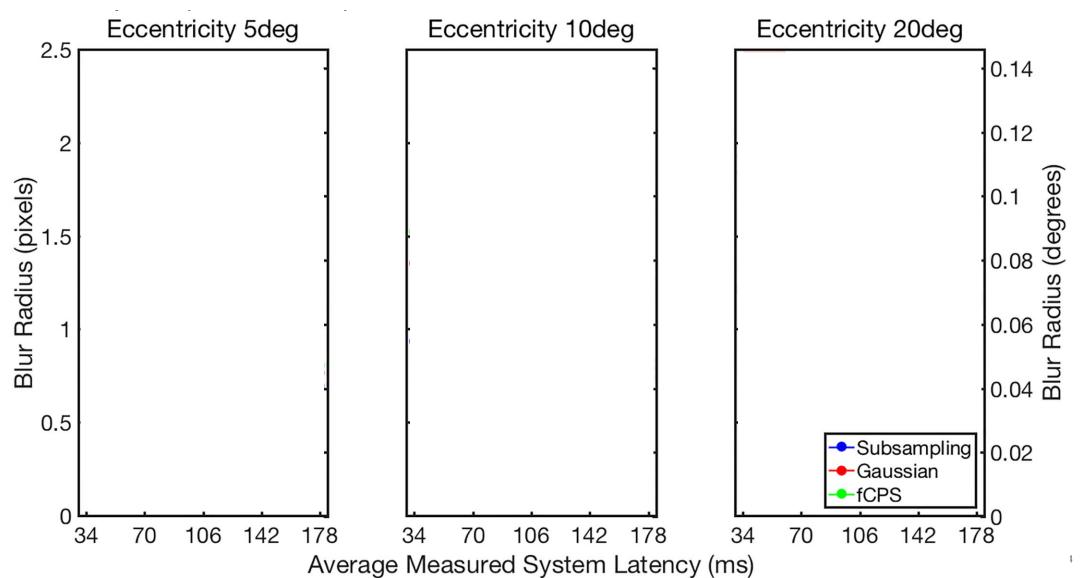


## **"MOTION TO PHOTON"** SACCADE START TO SCREEN UPDATE

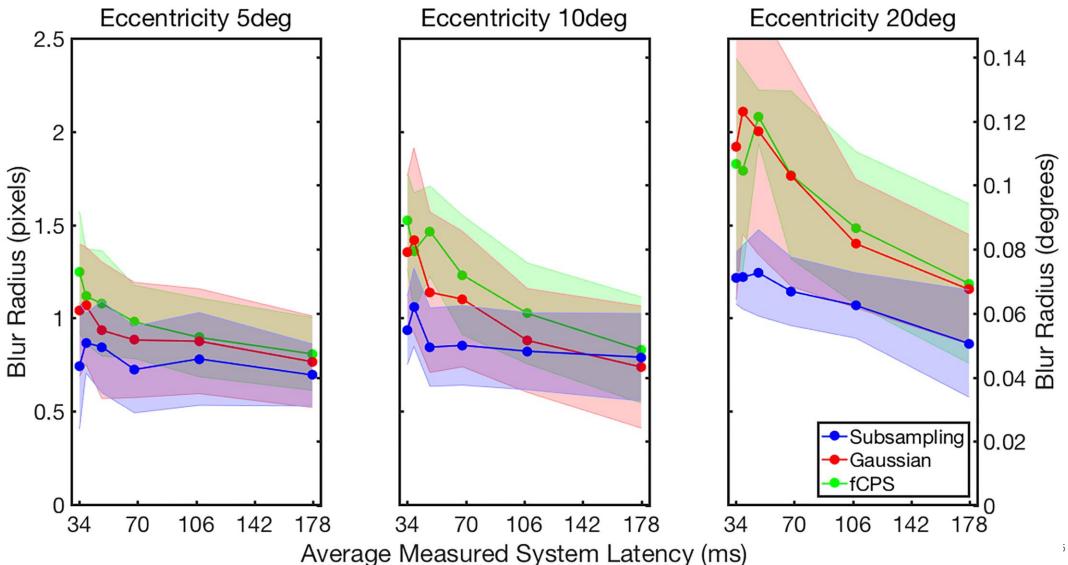
- HTC Vive + SMI Eye Tracker
- NVIDIA Titan X (Pascal) GPU + Falcor rendering framework



#### RESULTS

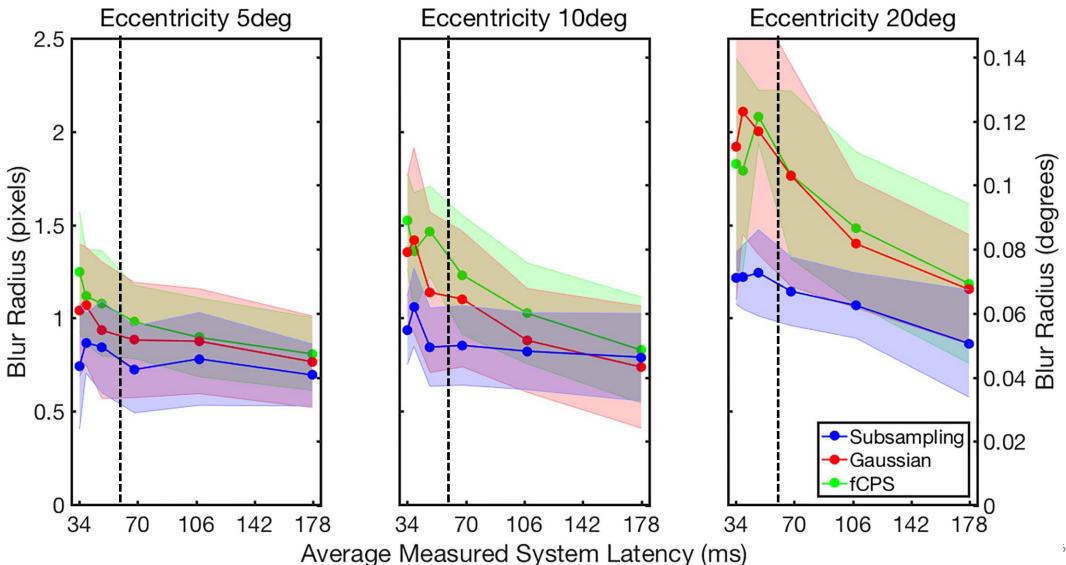


#### INTERACTION BETWEEN TECHNIQUE & ECCENTRICITY



📀 nvidia.

#### MAIN EFFECT OF LATENCY (THRESHOLD AT 50-70 MS)

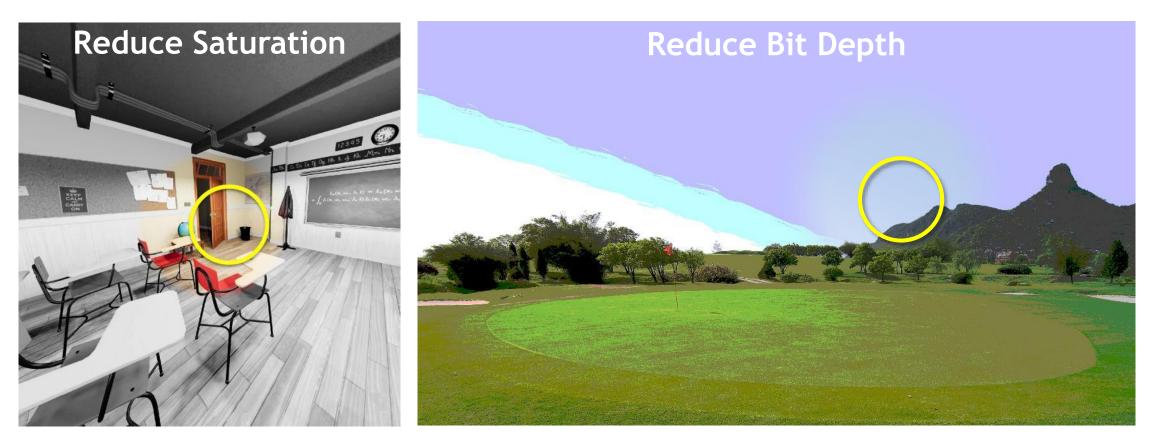


💿 💿 🕺 🕺

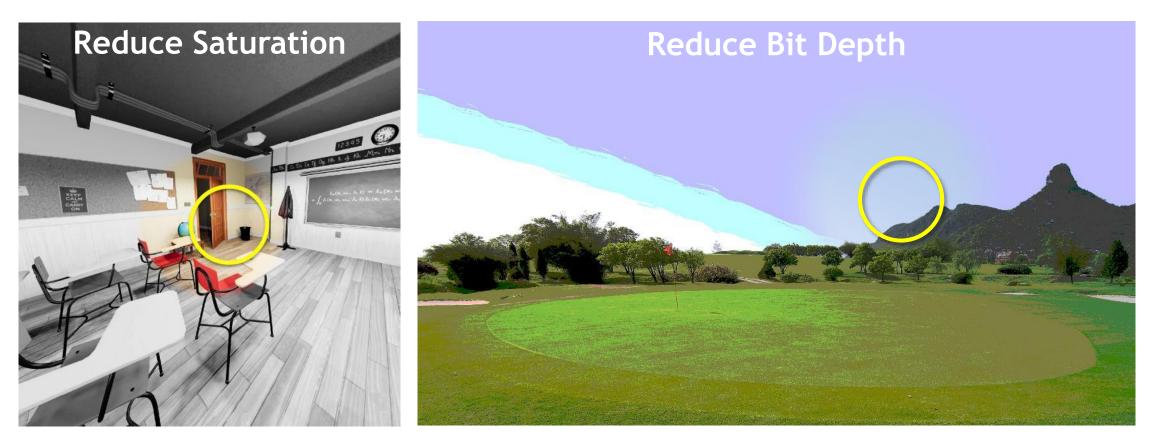
# LATENCY EXPERIMENT TAKEAWAY POINTS

- Temporally stable foveation methods support more foveation at larger eccentricities
- All foveation methods and eccentricities show significantly worse performance above 50-70 ms latency

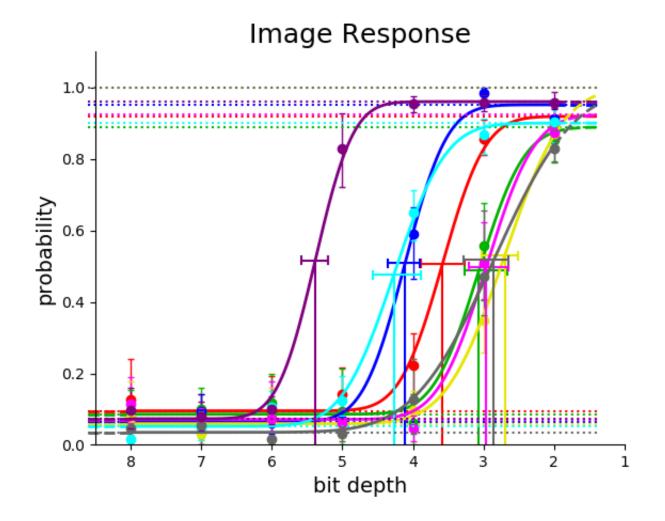
#### PERIPHERALLY DEGRADING IMAGES WITH COLOR



#### PERIPHERALLY DEGRADING IMAGES WITH COLOR

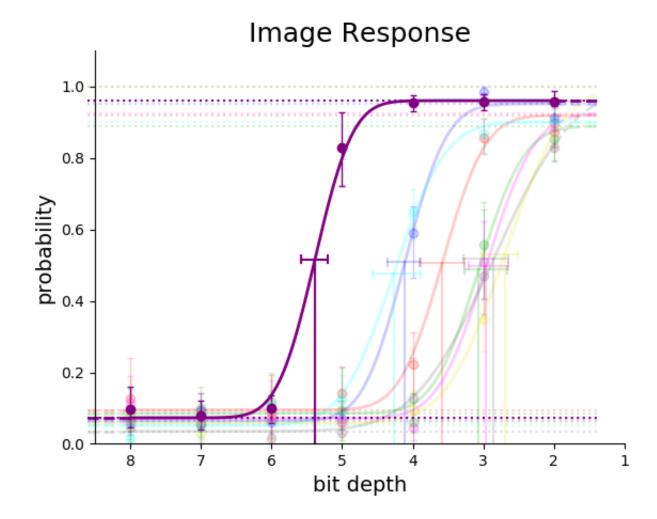


## EXPERIMENT: REDUCE BIT DEPTH WHEN DOES THE VIEWER SEE FOVEATION?



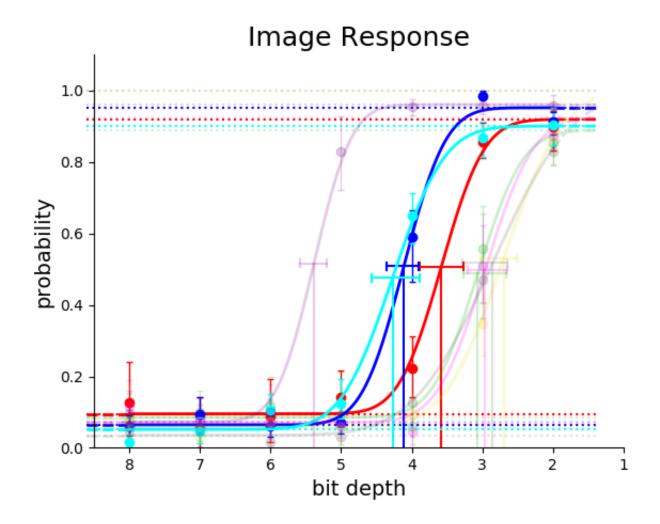


## **RESULT: LOW SPATIAL FREQUENCY CONTENT**



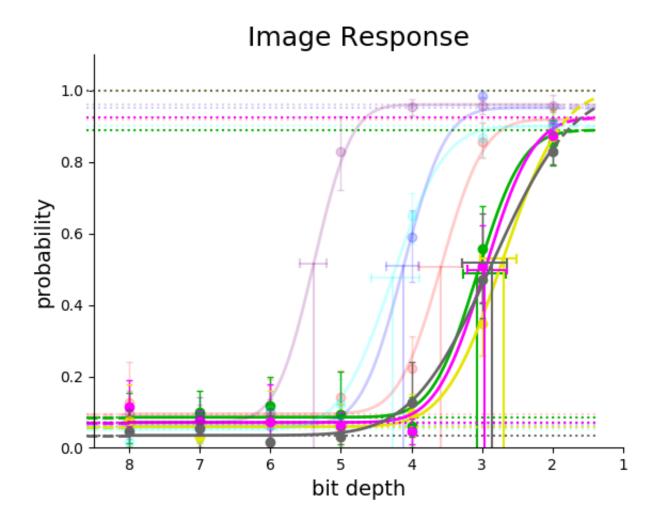


### **RESULT: MID SPATIAL FREQUENCY CONTENT**





## **RESULT: HIGH SPATIAL FREQUENCY CONTENT**





## **COLOR EXPERIMENT TAKEAWAY POINTS**

- Some bit depth reduction is not noticeable in the periphery
- The level of acceptable bit depth reduction is highly dependent on spatial frequency of the content

#### **BIGGEST CHALLENGE: TEXT**

#### High Contrast, High Spatial Frequency Content

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#### Aliasing produces flicker

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#### Blurring breaks contrast constancy

#### PERIPHERAL SPATIAL METAMERS

Original Image





Metamer #2



Freeman & Simoncelli, 2011

## PERIPHERAL SPATIAL METAMERS

- Lossy compression of spatial information
- Peripheral perception is complicated





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# **THANK YOU**









# 60 MS TO GET IT, RIGHT GAZE-CONTINGENT RENDERING & HUMAN PERCEPTION

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## **EXPERIMENTAL DESIGN**

- Task move eyes and head to try to see artifacts
   4 second stimulus duration per trial
   Yes/No Response ("Did you see any artifacts?")
- Amount of foveation varied based on responses

   up/1 down adaptive staircase
   Foveation level = shading rate per 2^N pixels (higher is better)
- Controlled for actual system latency, head & eye motion

### SYSTEM REQUIREMENTS FOR GAZE-CONTINGENT RENDERING





Eye Tracking

- Accurate
- Fast





#### Rendering

- Cheap, Fast
- Perceptually Matched

#### Display

- Low Persistence
- Low Latency