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Vergence-Accommodation Conflicts in Augmented Reality -Impacts on Perceived Image Quality-

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@facebook AR/VR Applied Perception Science

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Paper Session19, Paper 2, Section 469

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Summary

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Study Goal

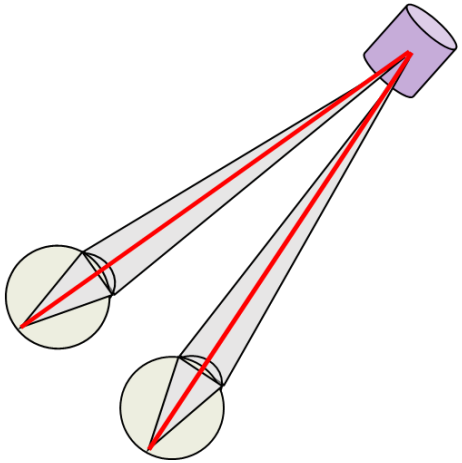
- Understand the impact that vergence-accommodation conflicts (VAC) have on image quality in the context of an augmented reality environment

Outline

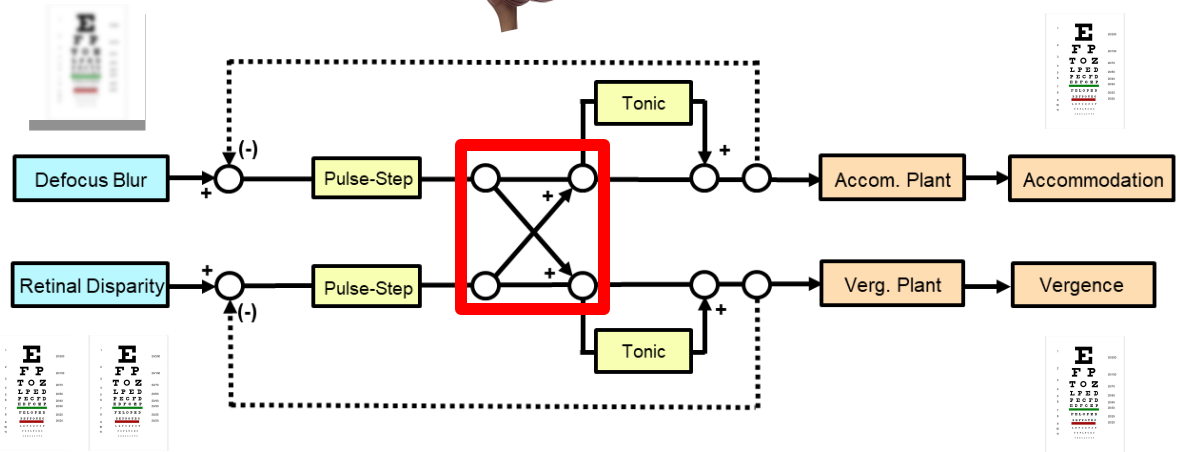
- Determine detection thresholds for focal rivalry for spatially congruent content

- Review vergence-accommodation conflicts (VR vs AR)
- Study Apparatus, Design & Analysis
- Results
- Conclusions & Next Steps

Vergence & Accommodation

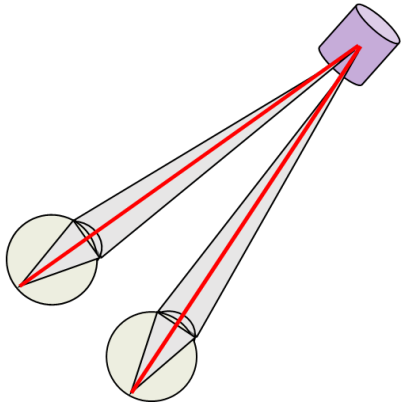


The World

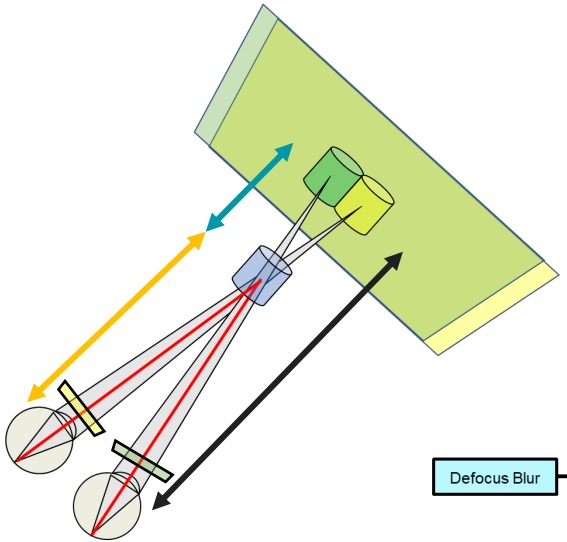


Modified from Schor, 1992. Opt. Vis. Sci.

Vergence Accommodation Conflicts (VAC)



The World



VR Environments

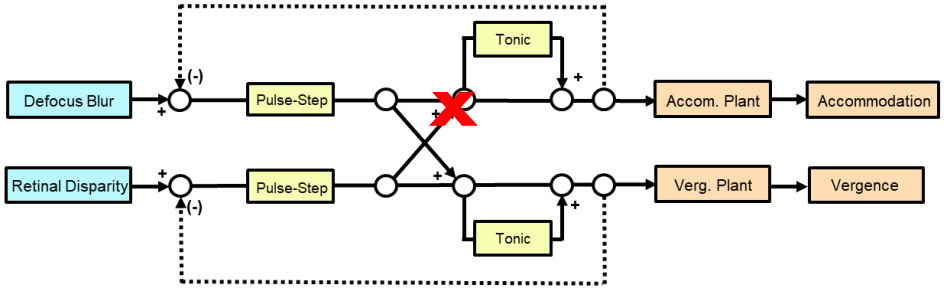
Virtual Image Distance (VID)

-

Disparity-Depth Location of Rendered Image

=

VAC Magnitude



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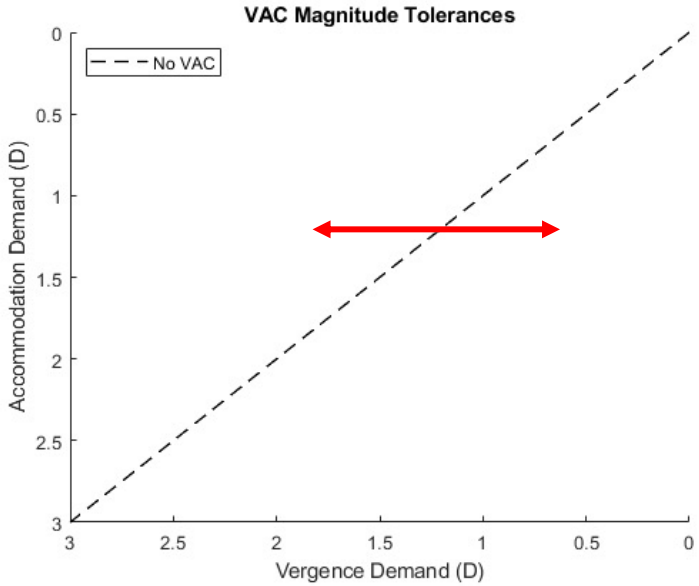
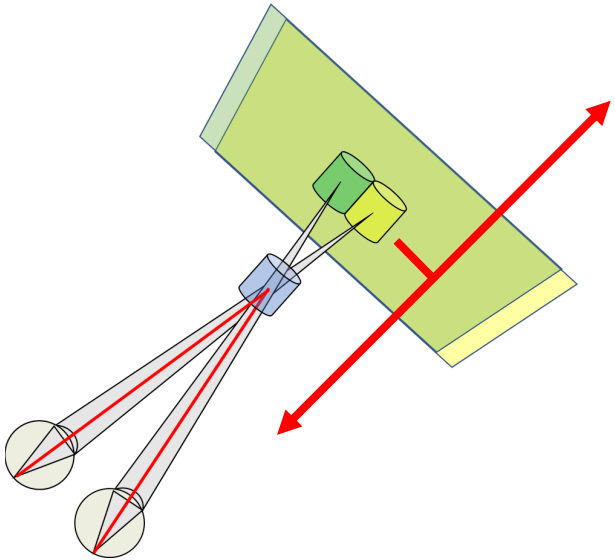
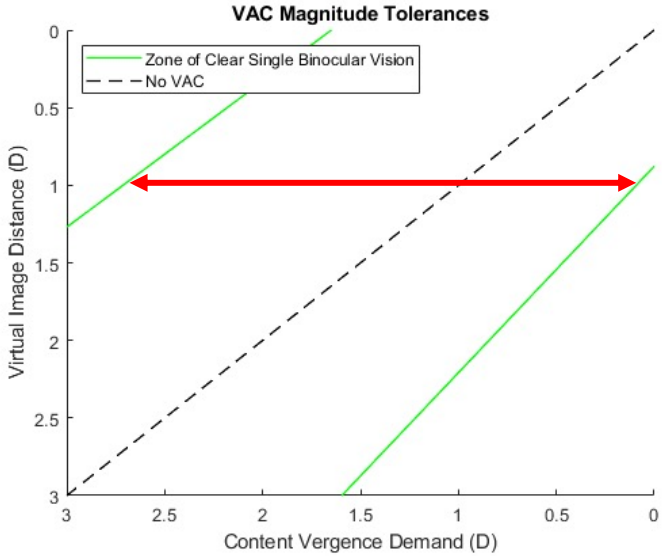
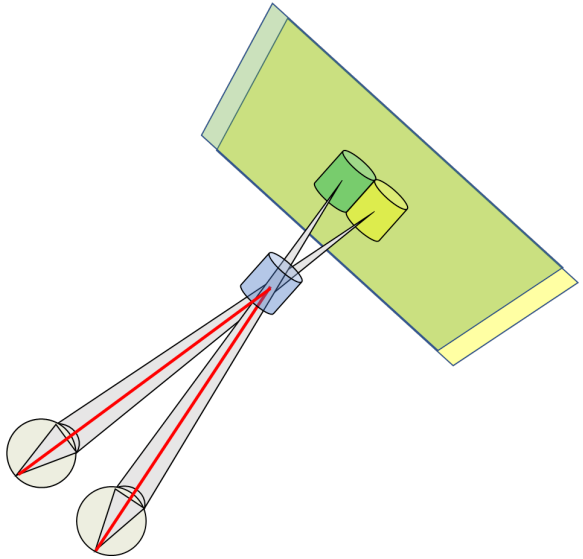
VAC Tolerance in VR

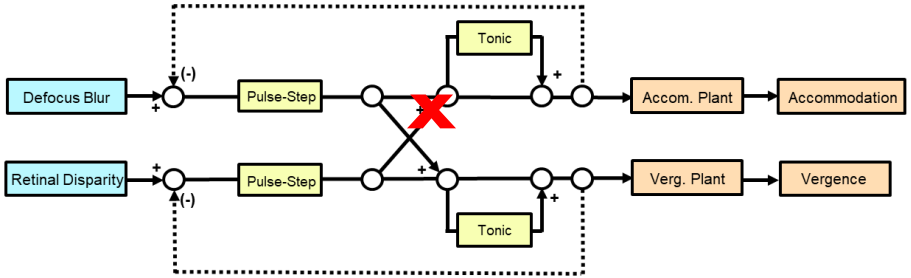




VAC Tolerance in VR







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The VR-VAC 'Zone of Comfort'

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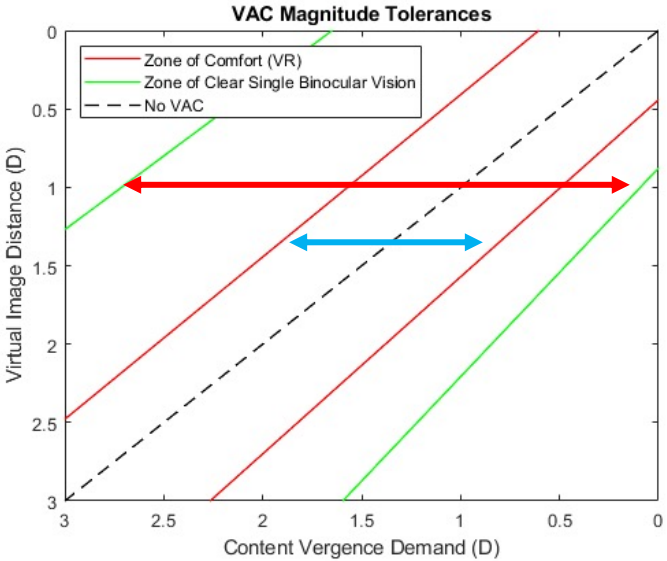

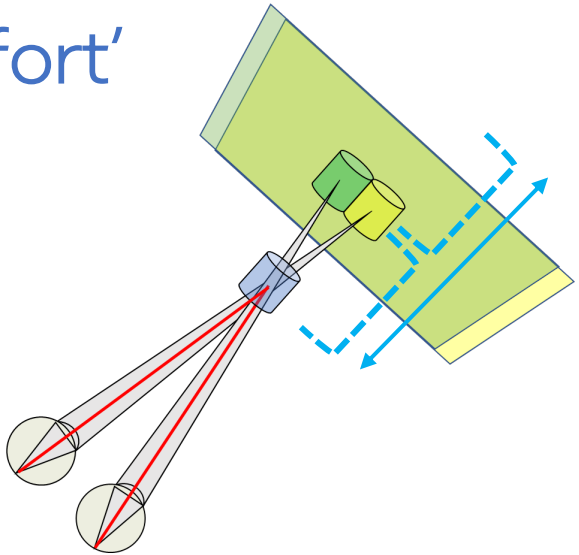

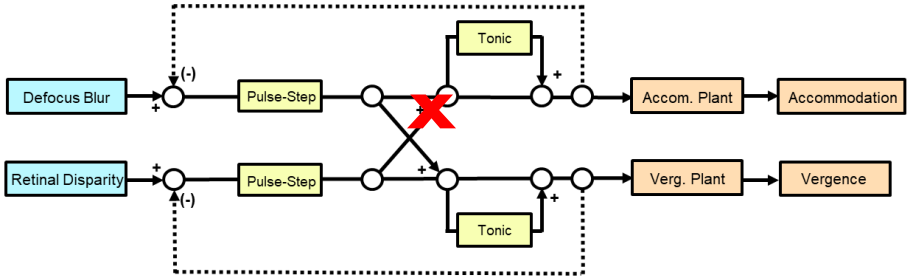

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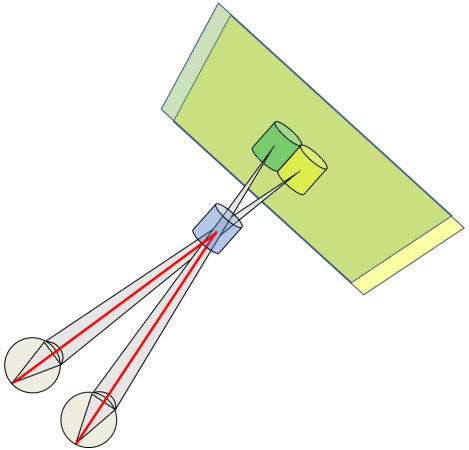
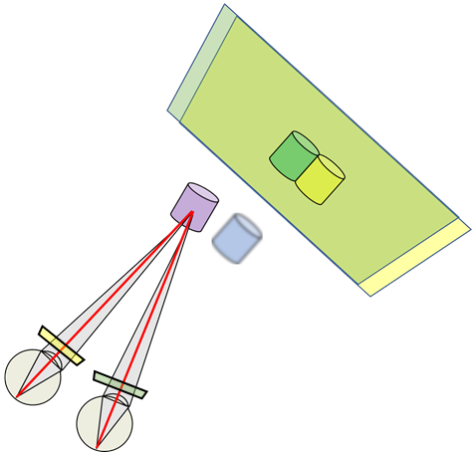
Banks et al. 2013. "Insight into Vergence/Accommodation Mismatch." 8735: 873509.

VR vs AR VAC

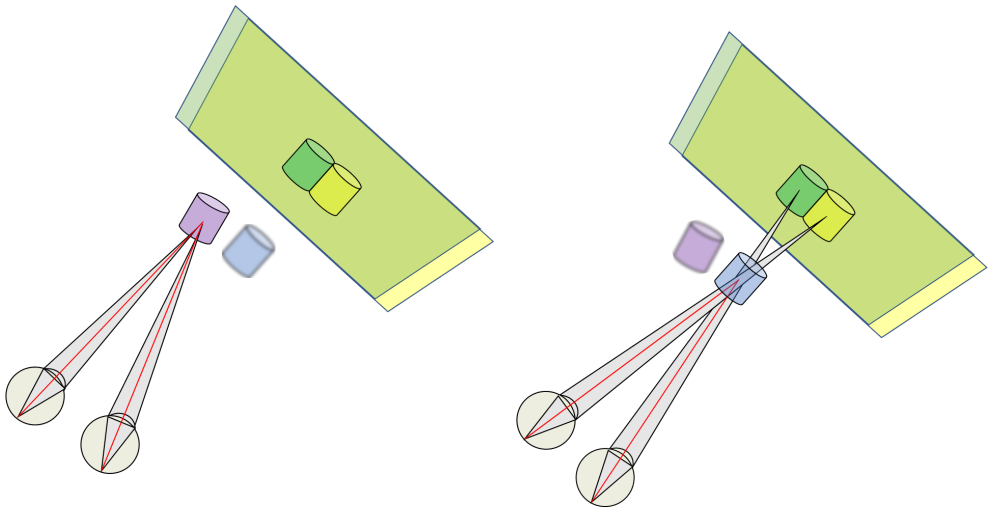


VR Environments



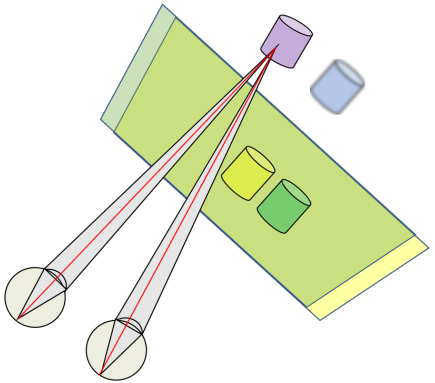
AR Environments

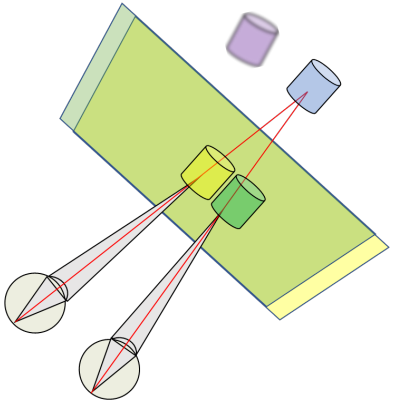
AR VAC



Positive (AR) VAC

Negative (AR) VAC





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Study Goals

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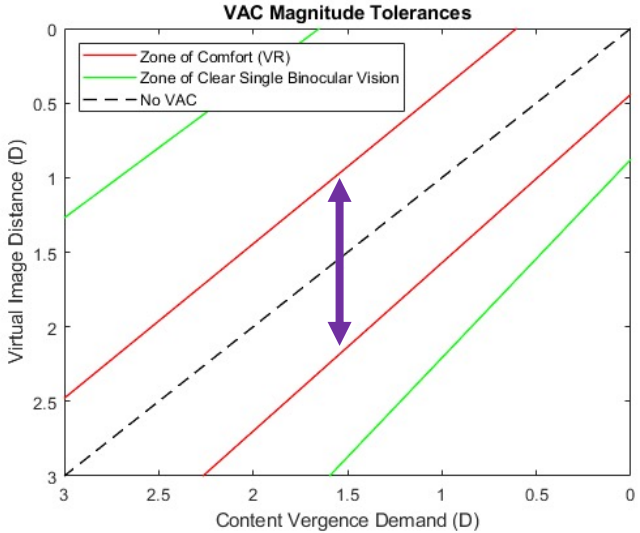
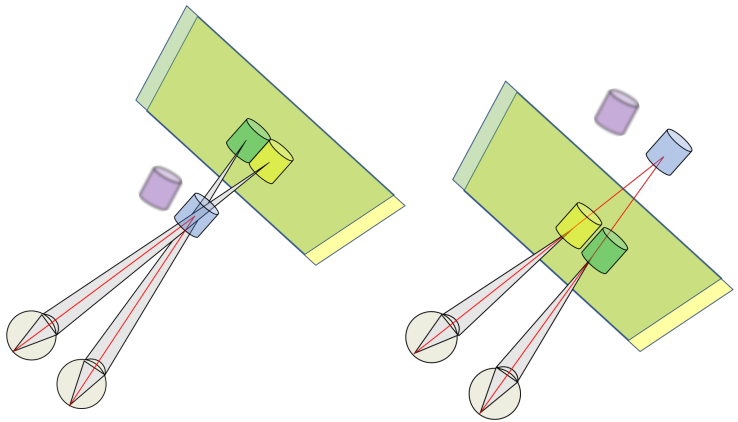
- Evaluate the impact of VAC in AR on perceived image quality
  - Detection thresholds of focal rivalry induced blur between spatially congruent content & real-world objects
  - Quantify content limitations that the HVS imposes in AR
    - Under specific, worst case, circumstances





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Experiment Platform

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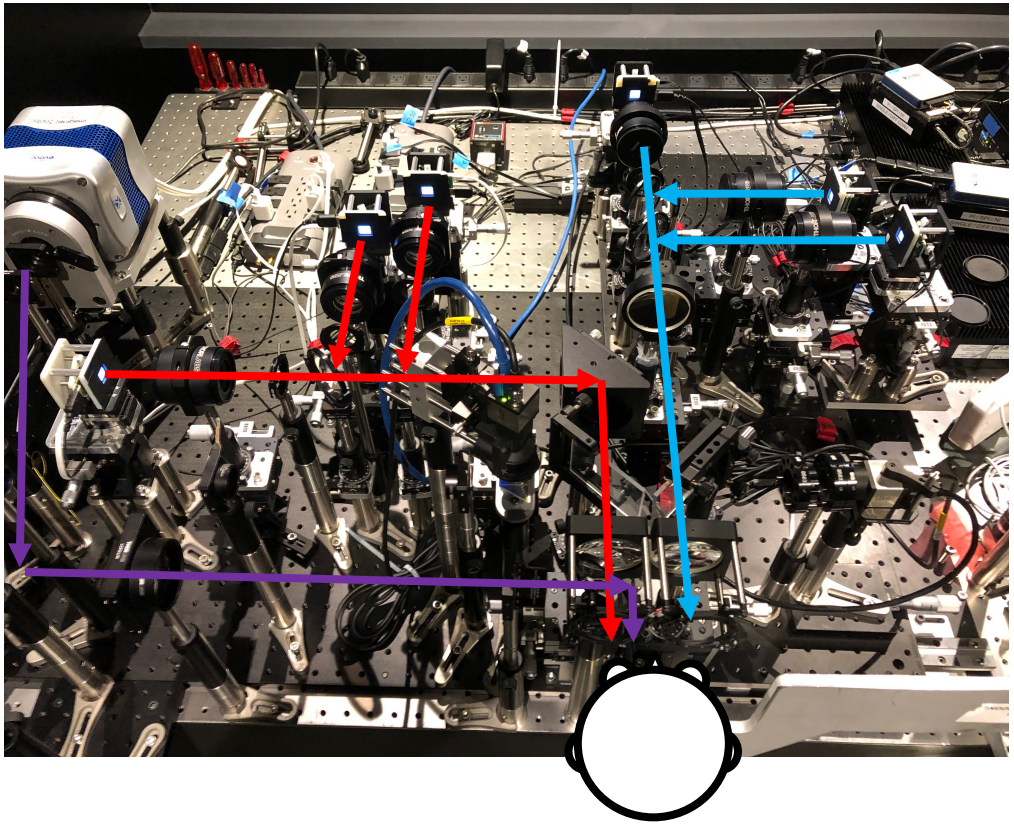
- High Resolution Additive Display System -



- 3 displays per eye (6 total)
  - Variable focus for each display
  - Telecentric
  - 2arcm resolution
  - Luminance & white point balanced

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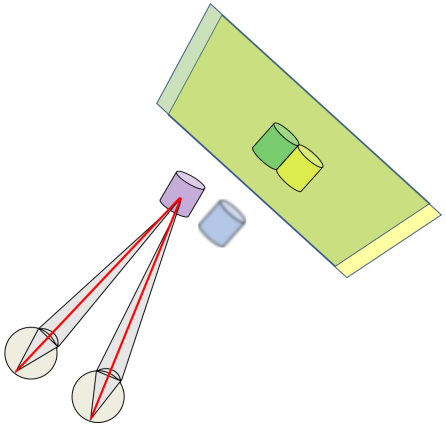
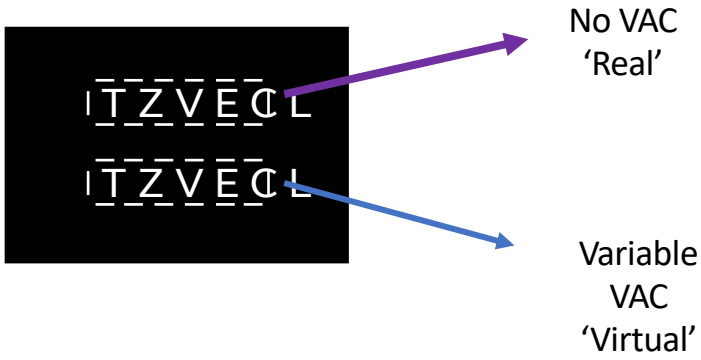
Experiment Design & Stimlus

- 2AFC Task, n = 11
  - Blur discrimination threshold for simultaneous viewing of content with and without VAC
  - *'Which text is clearer when you focus naturally?'*

- 3 VIDs (0.5D, 1D, 1.67D)
  - VAC varied by ~0.25D steps up to 2D maximum VAC
  - 12 trials @ each VAC condition per VID
  - 1 control condition per focal plane
    - Both sets of text have ***no*** VAC
  - 468 trials per participant (excluding practice trials)





Experiment Design

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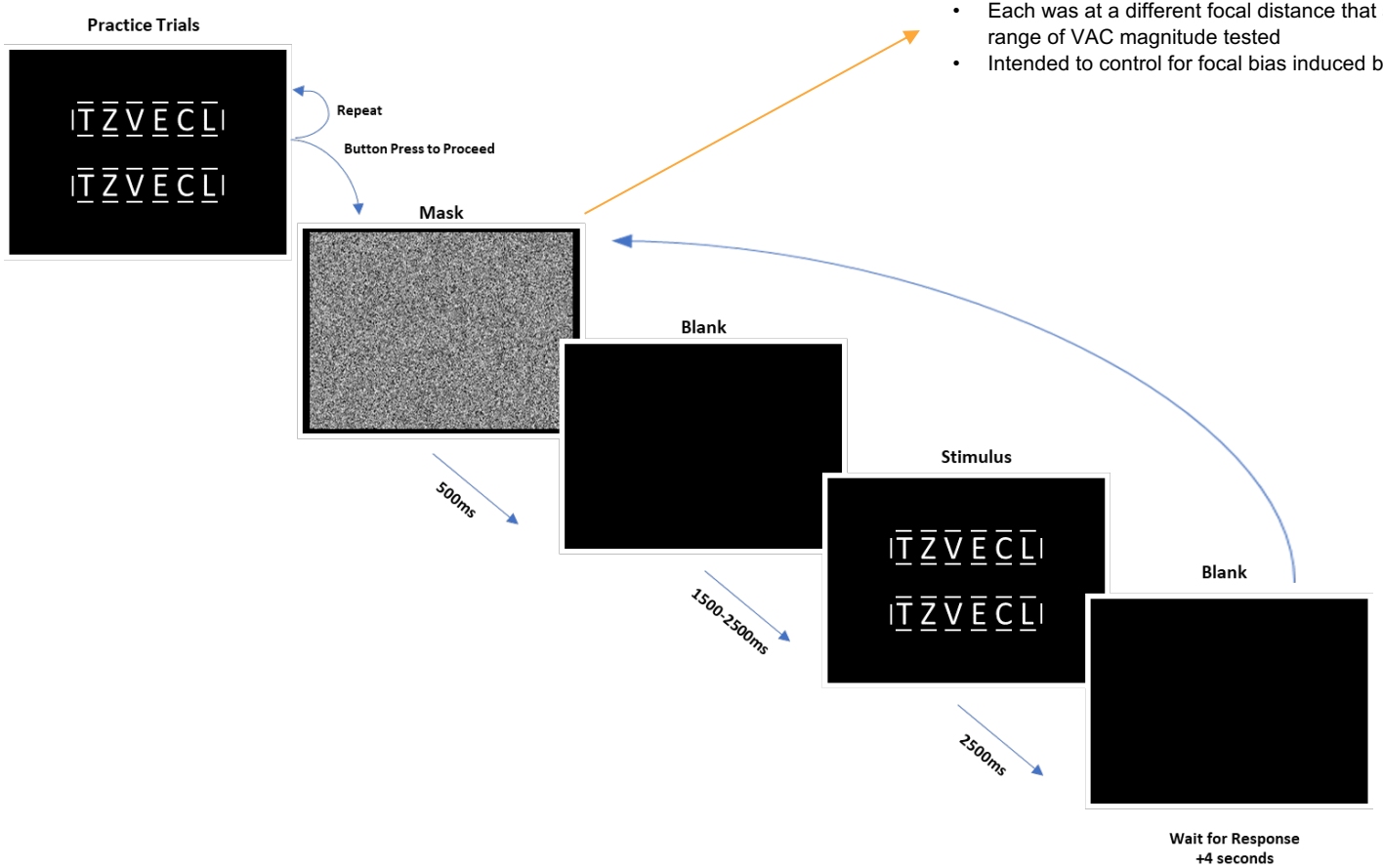
- Mask was rendered on all 3 binocular display sets
- Each was at a different focal distance that spanned the range of VAC magnitude tested
- Intended to control for focal bias induced by mask



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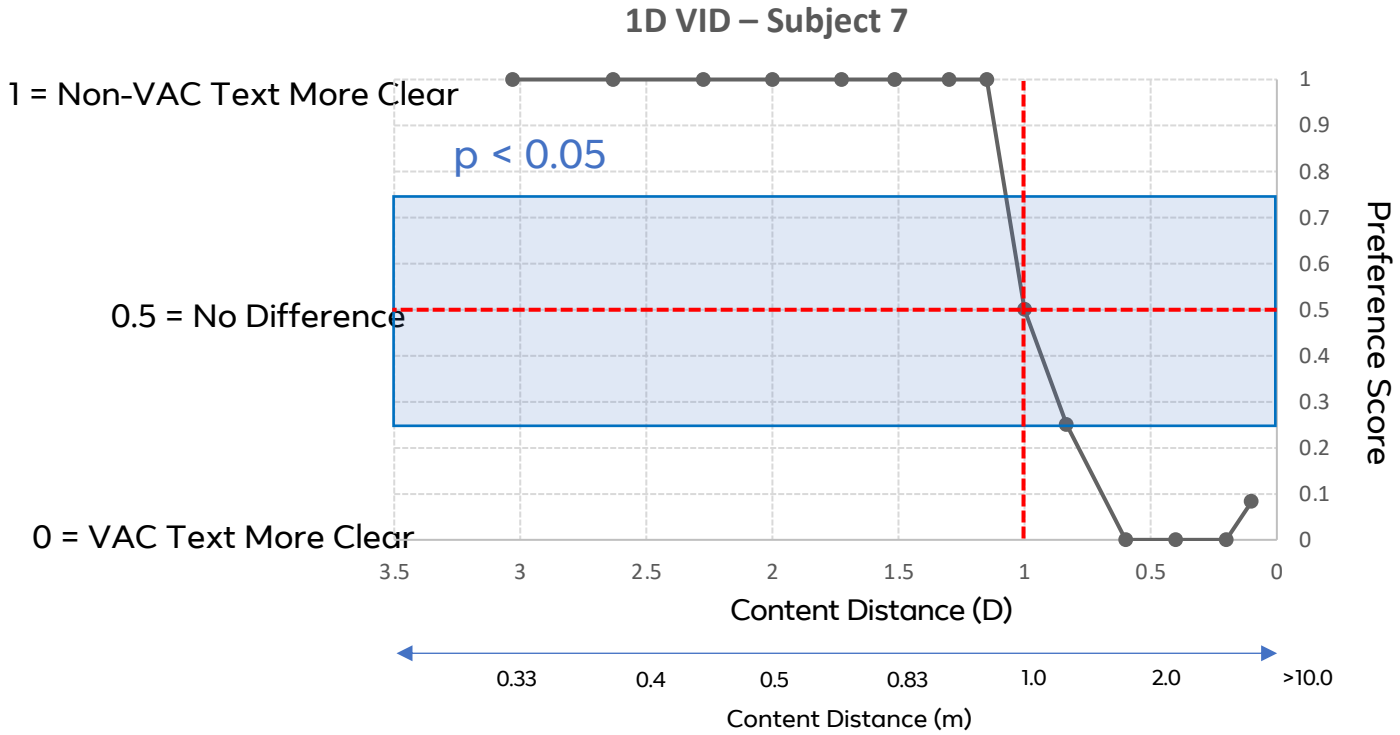
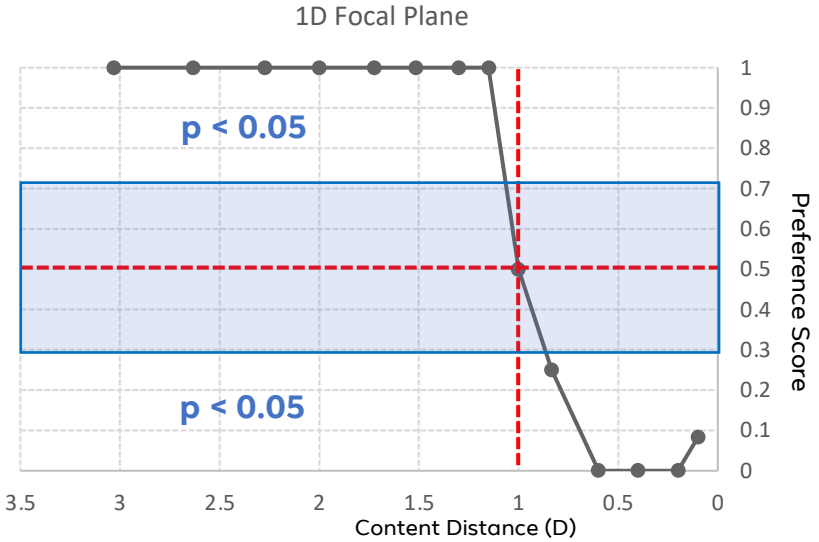
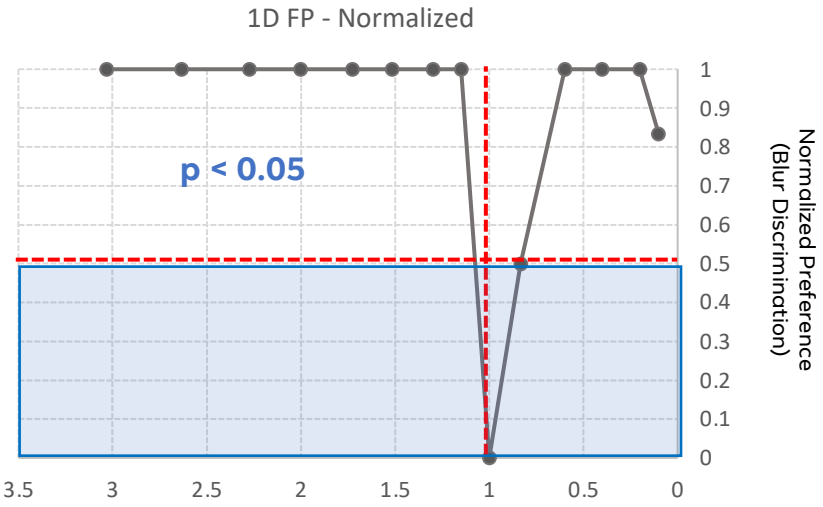
Results – Raw Data



Data Normalization – Focal Rivalry Blur Discrimination





$$Normalized\ Preference = \frac{\left| Preference\ Score \right|}{0.5}$$

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Threshold Determination – Individual Data

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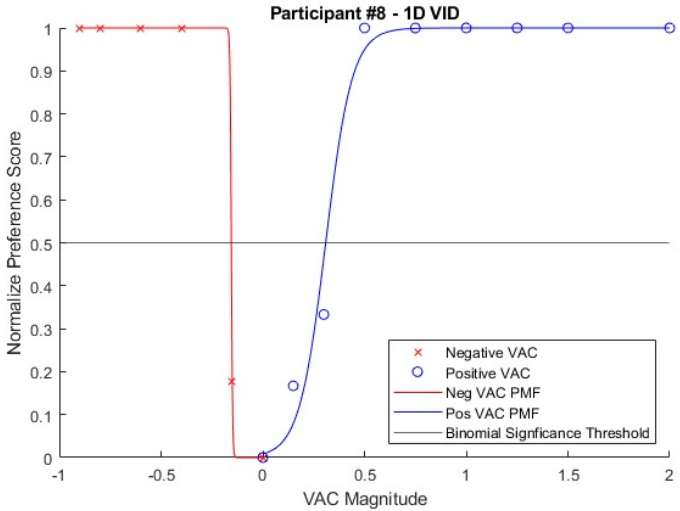
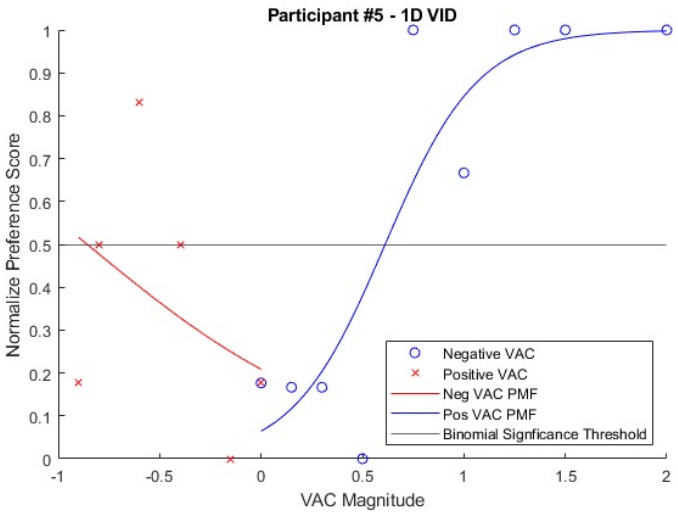
- Quality of fit for the psychometric function on the normalized data varied significantly between participants
  - Larger VAC magnitudes influenced responses for only some individuals

- Threshold = first VAC magnitude where normalized preference score > binomial sig test @ $p < 0.05$





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Individual Preference for Content Type

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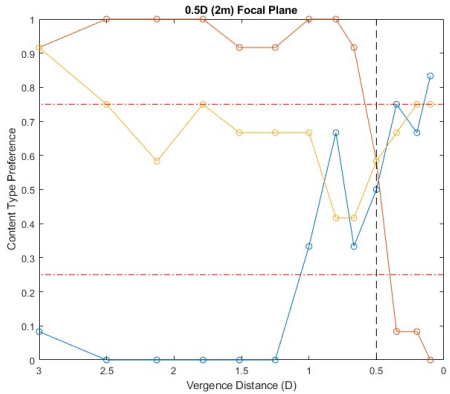
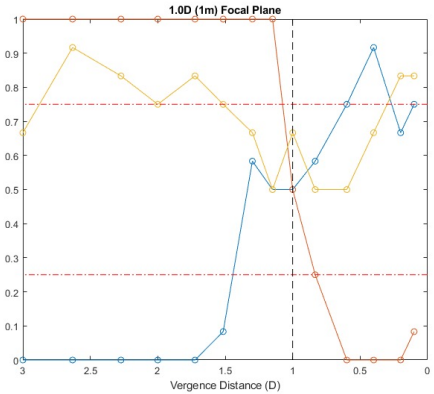
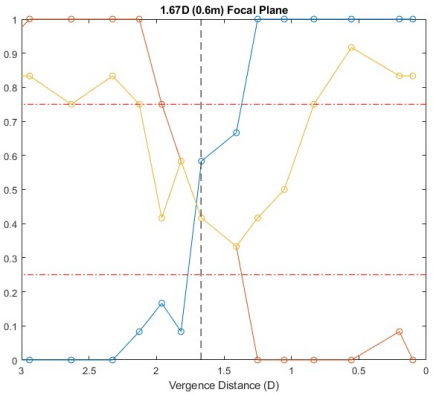
- Preference for which content type was clearest was idiosyncratic between participants
  - Influenced by VAC direction in some observers
    - 8 of 11 had the same preference pattern regardless of VID (as shown)
      - 3/8 preferred VAC content when VAC was negative & non-VAC content when VAC was positive (red)
      - 2/8 preferred VAC content when VAC was positive & VAC content when VAC was negative (blue)
      - 1/8 always preferred VAC content
      - 2/8 always preferred non-VAC content (this was the expected pattern but only occurred in 2/12 observers)
    - 3 of 11 had a change in content preference for a VAC direction based on VID







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Heterophoria & Preference for Content Type

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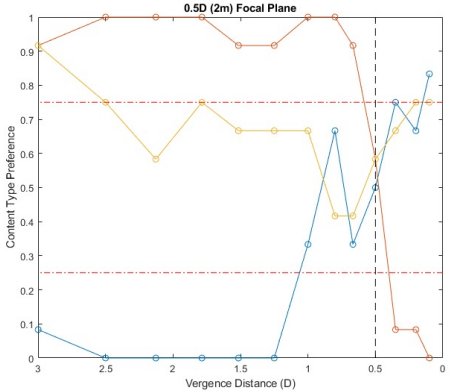
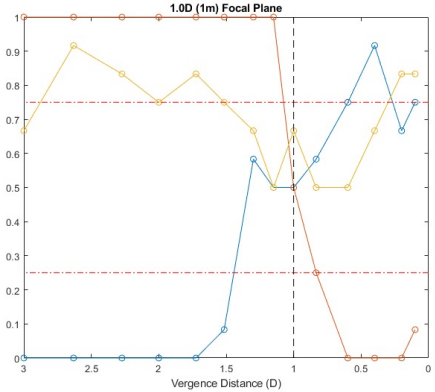
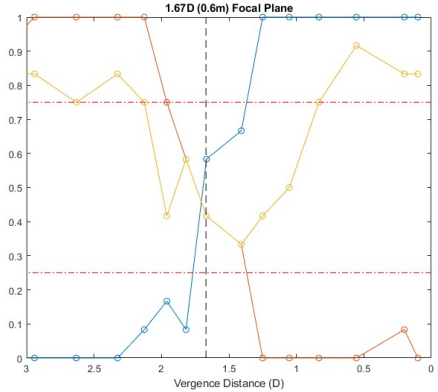
- We investigated the role that the observers heterophoria played in these idiosyncratic differences in preference of content.
- Wilcoxon SRT for each VID condition
  - Heterophoria type vs Content Preference
  - No effect at any VID ($p > 0.05$)
- Did not measure dark focus (tonic accommodation); however we hypothesize this may play a role.
  - May act as an 'anchor' for accommodation when presented with significant defocus gradient between 2 spatially congruent targets.







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Group Normalized Preference-Probability

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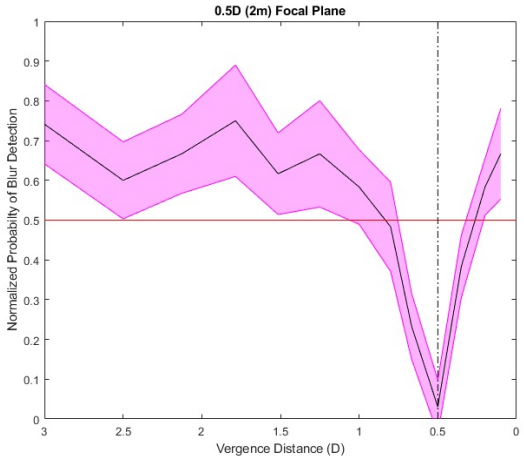

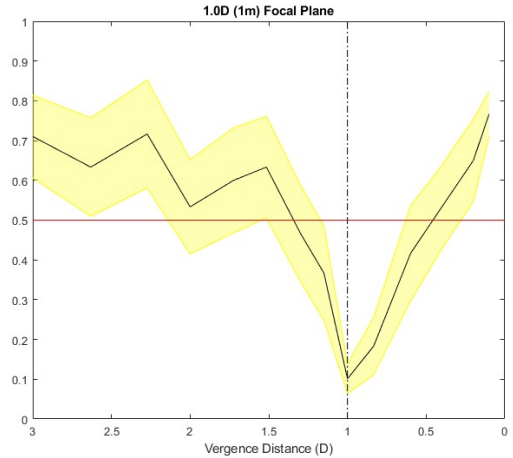

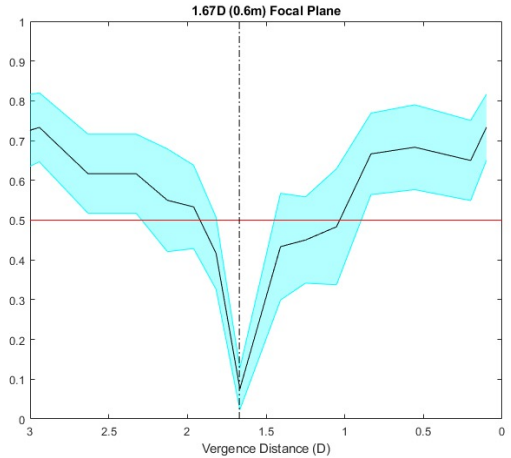

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The (AR) Zone of Clear Vision - 'ZoCV'

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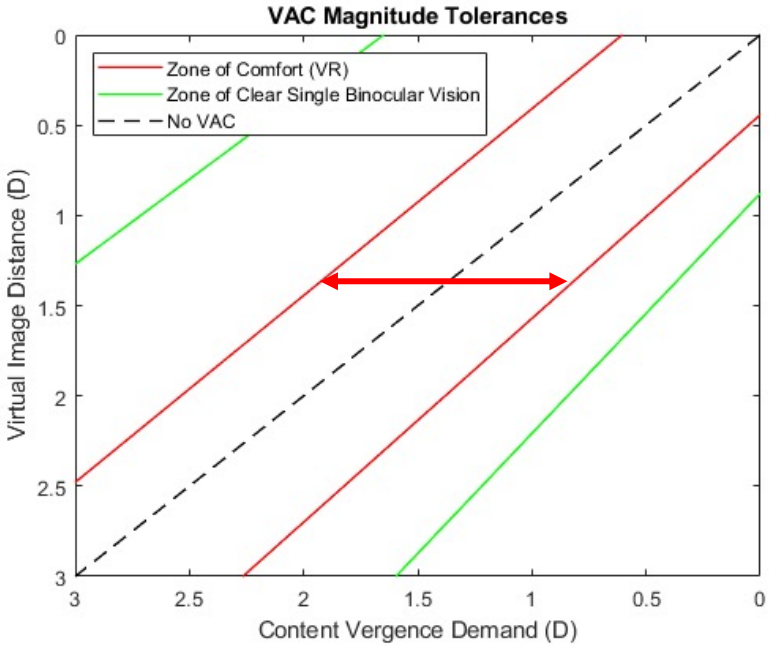

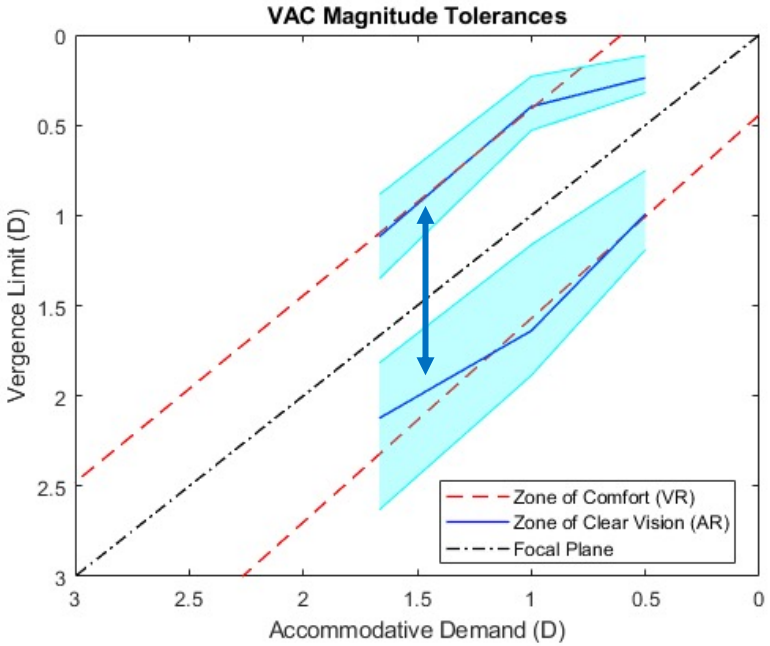

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Conclusions & Next Steps

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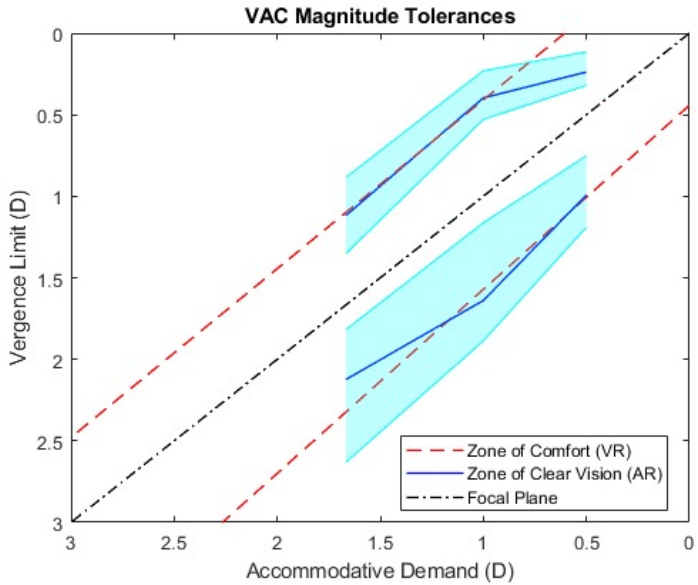
1. Some participants preferred VAC Content
   - AR may impact visibility/visual quality of the real world

2. Large VAC magnitudes in AR can impact user performance on this task
   - Need to understand oculomotor responses to these types of stimuli (accommodation)

3. The ZoCV is in magnitude (width) as the ZoC for VR
   - Suggests that image quality may provide an indirect measure of visual discomfort
   - Individual physiology (pupil size, optics) may account for interobserver variability



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