# A re-examination of dichoptic tone mapping methods

Minqi Wang[1], Emily A. Cooper[1,2]
[1]School of Optometry and Vision Science Program, [2]Helen Wills Neuroscience Institute
University of California, Berkeley

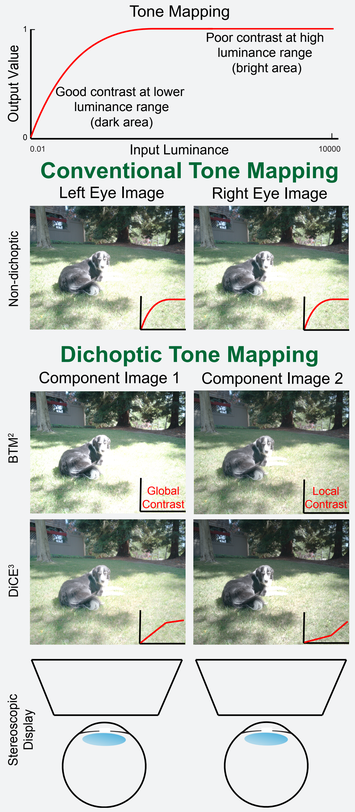
## Introduction

**A good visual reproduction recreates the visual experience of a real scene using a different medium.** In digital imaging, tone mapping methods are often needed to map the large range of luminance levels found in natural scenes to a restricted range of pixel values amendable to conventional cameras and displays[1].

**Tone mapping methods often produce images that lack visible detail in the highlights or lowlights of a scene.** In the example images on the right, sometimes visible detail is missing in the bright grassy area, and sometimes visible detail is missing in the darker background.

**With the rise of stereoscopic displays, novel *dichoptic tone mapping* methods have recently been proposed to boost visible detail through binocular combination[2,3,4,5,6].** Psychophysical work suggests that when images with different contrast levels are presented to each eye, the percept will often be dominated by the higher contrast image[7,8,9]. Thus, it seems reasonable, for example, that if one eye views a tone map with better highlights and the other eye views a tone map with better lowlights (see DiCE, with 2 different tone curves shown), the fused binocular percept would contain more contrast across the scene than each eye's component image alone.

**However, perceptual assessments of dichoptically tone mapped images have produced mixed results for improving perceptual quality.** Some work suggests that a range of dichoptic methods are highly effective in improving subjective image quality consistently over non-dichoptic methods across different tasks[2,5,6], but a recent study found mixed results depending on the task directions, image, and tone mapping method[3]. We hypothesized that these conflicting results found in previous studies were primarily related to the different baseline tone mapping methods used in perceptual comparisons[2,3]. Thus, we performed several new evaluations to reassess two recent dichoptic tone mapping methods[2,3].




**Question: Are perceptual impressions of images generated with dichoptic tone mapping consistently better than impressions of images generated with conventional tone mapping?**

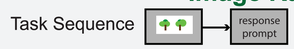
## Methods

We examined how people percieve images generated via dichoptic tone mapping methods from Zhang et al. (BTM)[2] and Zhong et al.(DiCE)[3] as compared to several non-dichoptic methods. We tested three criteria across several studies, including: **overall image preference, detail visibility, and 3D impression**. All images were generated from the same publicly available image dataset[10] and were not stereoscopic.

In each experiment, we compared each dichoptic tone mapping method against several non-dichoptic methods. In non-dichoptic conditions, both eyes viewed the same tone map. For these non-dichoptic conditions, we used each component image from the dichoptic pair (C1, C2). In addition, the BTM[2] dichoptic method was also compared to a non-dichoptic image that was the average of the two component images (Average).

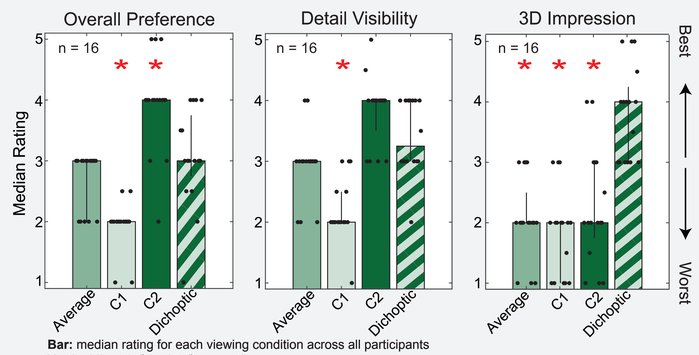
## Results

### Image Rating (BTM)




On a scale 1-5, rate according to overall preference, detail visibility or 3D impression, 5 is best.

**Dichoptic pair was not consistently rated higher than both of its component images for overall preference and detail visibility, but was highly rated for 3D impression.**

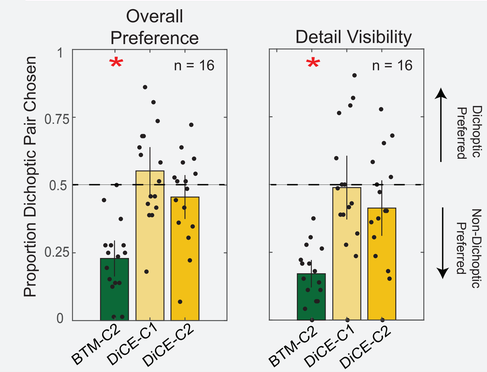



**Bar:** median rating for each viewing condition across all participants
**Vertical line:** 25th and 75th percentile
* Indicate the non-dichoptic conditions that are significantly different from the dichoptic condition using pairwise Wilcoxon signed-rank test (p<0.05).

### Two-Alternative Forced Choice (BTM, DiCE)


Which image (1st or 2nd) had better image quality or detail visibility?

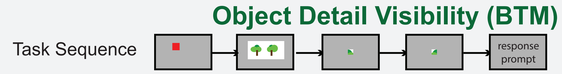
**Dichoptic pair was not preferred over both of its component images for overall preference and detail visibility.**




**Bar:** mean proportion each dichoptic pair is chosen over its non-dichoptic component(s)
**Vertical line:** 95% confidence interval
**Dashed line:** chance performance.

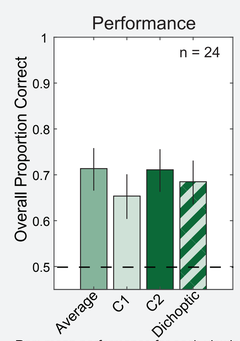
* Indicate the comparisons with significant difference between choosing dichoptic and non-dichoptic using t-test (p<0.05)

### Object Detail Visibility (BTM)



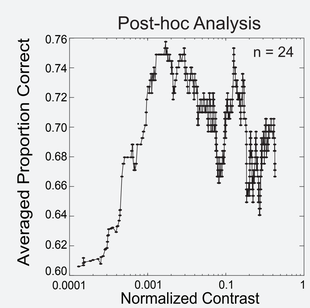

Which patch (1st or 2nd) matched the orientation seen in the scene?

**Dichoptic pair did not improve performance on visible detail task compared to non-dichoptic images.**




**Bar:** mean performance for each viewing condition across all participants
**Vertical line:** 95% confidence interval.
**Dashed line:** chance performance.

| Logistic Regression Model Fit | | | |
|---|---|---|---|
| Condition | *Coefficient* | *Odds Ratio* | *pValue* |
| Average | 0.114 | 1.30 | 0.25 |
| C1 | -0.18 | 0.66 | 0.06 |
| C2 | 0.10 | 1.26 | 0.32 |




**Is this task a good objective measure for percieved detail?**

At low contrast levels, performance is correlated with contrast. But this is not the case for higher contrast, suggesting factors other than contrast influence performance.

**Logistic regression model fitting trial-by-trial data**

Compares each non-dichoptic condition against the dichoptic condition with viewing conditions as categorical predictors, and both participant and scene as random effects

## Conclusion

By comparing two existing dichoptic methods against several non-dichoptic methods using different tasks, we found that these dichoptic tone mapping methods:

- did not produce consistent improvements over non-dichoptic methods in terms of overall image preference and detail visibility. The previously found positive results may be driven by one of the component images from the dichoptic pair, but not the dichoptic method per se.
- could create a robust augmentation to the viewer's percept as indicated by results for 3D impression, even though all the images wee non-stereoscopic.

A follow-up analysis showed no difference in image rating as a function of the sensory eye dominance of the participants.

**Future work:** These results indicate that there is more to be understood about binocular combination of natural images. Understanding the effects of natural pattern and context on binocular combination will help us develop better dichoptic methods for stereoscopic displays and better predictions for their perceptual outcomes.

## Acknowledgements

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## References

1. DiCarlo & Wandell (2000). Rendering High Dynamic Range Images. In Sensors and Camera Systems for Scientific, Industrial, and Digital Pho-tography Applications.
2. Zhang, Hu, Liu, & Wong (2018). Binocular Tone Mapping with Improved Overall Contrast and Local Details.Computer Graphics Forum.
3. Zhong, Koulieris, Drettakis, Banks, Chambe, Durand, & Mantiuk (2019). DiCE: Dichoptic Contrast Enhancement for VR and Stereo Displays. ACM Transactions on Graphics (SIGGRAPH Asia Conference Proceedings).
4. Feng & Loew (2017). Video-Level Binocular Tone-Mapping Framework Based on Temporal Coherency Algorithm. In 2017 IEEE Applied Imagery Pattern Recognition Workshop (AIPR).
5. Zhang, Han, He, Liu, Zhu, Hu, & Wong (2019). Deep Binocular Tone Mapping.The Visual Computer.
6. Yang, Zhang, Wong, & Heng (2012). Binocular Tone Mapping. ACM Transactions on Graphics (SIGGRAPH Conference Proceedings).
7. Kingdom & Libenson (2015). Dichoptic Colour Saturation Masking is Unmasked by Binocular Luminance Contrast. Vision Research.
8. Legge & Rubin (1981). Binocular Interactions in Suprathreshold Contrast Perception.Perception & Psychophysics
9. Ding, Klein, & Levi (2013). Binocular Combination of Phase and Contrast Explained by a Gain-Control and Gain-Enhancement Model. Journal of Vision.
10. Hasinoff, Sharlet, Geiss, Adams, Barron, Kainz, Chen, & Levoy (2016). Burst Photographyfor High Dynamic Range and Low-Light Imaging on Mobile Cameras.ACM Transactions on Graphics.