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Metasurface-based contact lenses for color vision deficiency: comment

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Recently Karepov and Ellenbogen [Opt. Lett. 45, 1379 (2020)] claimed that a new metasurface-based contact lens is able to correct deuteranomaly. Unfortunately, their results are not supported by psychophysical experiments, and some key assumptions in their simulations were misinterpreted. All of this has led to wrong conclusions providing false expectations to the color vision deficiency community.

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Karepov and Ellenbogen [1] wrote that "... using glasses with color filters for improvement of color perception is widely accepted..." and claimed that with a particular filter the spectral response of the M-cone can be attenuated and, consequently, "the color vision deficiency could be restored." This idea has been widely scientifically refuted in other implementations, as the cases of *EnChroma* or *VINO* glasses [2–5]. Through simulations and also psychophysical experiments, they [2–5] prove that these filters do not allow observers with color vision deficiency (CVD) to be able to perceive colors closer to the way normal trichromats do. Although the use of filters can have some limited utility depending on the task, like passing the Farnsworth-Munsell D15 or Ishihara tests [4–6], these filters will never "cure" or "correct" a CVD. Karepov and Ellenbogen introduce this filter in a new contact lens with plasmonic metasurfaces, to serve as a visual passive aid for CVD. No matter what technology is used to make it, any filter removes some of the spectral information and thus necessarily reduces the observer's gamut. In Ref. [1], no psychophysical experiments have been performed, using just an algorithm to simulate the perceived colors by deuteranomalous subjects. This algorithm has been incorrectly used due to the following discussed below.

The working color space is the particular space defined by the primaries of the *Edmund* microdisplay module [1], which is different from *CIE RGB* space. The standard transformation between *CIE RGB* and *CIE XYZ* has then been incorrectly used [1]. Besides, the transformation between *CIE RGB* and *CIELAB* is by no means linear, as the authors claim.

The computation of T matrices assumes that the luminances of the primaries in both color spaces are equal. Otherwise, these linear transformations are only valid to relate chromaticity coordinates [7]. Thus, in the Letter this assumption is wrongly used twice: in forward and backward steps. Consequently, the luminance of the final simulated colors is not accurate, especially in the case of deuteranomalous observers.

Besides, in the normalization of T matrices by k_C, it is assumed that $L = M = S = 1$ when $r^T = g^T = b^T = 1$. Thus, the neutral point of the LMS cone response is purely white, assuming that the monitor is calibrated ($r^T = g^T = b^T = 1$ means white) [7]. In the case of the cone space of deuteranomalous with the filter this means a complete chromatic adaptation, which is not supported by the literature [8].

We have computed simulations for normal and deuteranomalous observers, using the complete set of 1268 chips of the Munsell Book of Color, with Lucassen's CVD simulation method [4,5]. The color differences, considering the normal observer as reference, are as follows: average = 11.80, standard deviation = 9.57, and percentile 5 = 0.95 (no filter); average = 25.40, standard deviation = 8.16, and percentile 5 = 12.48 (proposed filter). In fact, 97.7% of the Munsell chips increase their color difference when using the filter with respect to the unfiltered case. This means that the results are worse when using the proposed filter in a vast set of color stimuli. This supports the hypothesis that the proposed filter in Ref. [1] cannot correct deuteranomaly.

To sum up, all these errors lead to wrong conclusions that contribute to extend information that is misleading.

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