Evaluation of color difference formulae for color rendering metrics

Wendy Davis and Yoshi Ohno
National Institute of Standards and Technology
Gaithersburg, MD, USA

Background

CIE's color rendering metric, the color rendering index (CRI) [1], will likely be updated or replaced in coming years. The CRI has a number of problems, including its use of the 1964 W*U*V* uniform color space. This color space is outdated and no longer recommended for use. Instead, the CIE currently recommends CIE 1976 L*a*b* (CIELAB) and CIE 1976 L*u*v* (CIELUV) [2] spaces. CIELAB is widely used in many applications, and it seems reasonable that it will be used in a new color rendering metric. The calculation of color differences ΔE^*_{ab} is simply the Euclidian distance between points in the CIELAB color space.

CIELAB is not without its own problems, as a number of researchers have conducted vision experiments that show that perceived color differences are not uniform across the space [e.g., 3]. To attempt to correct for the known non-uniformities, different methods of calculating color differences have been proposed, most recently ΔE_{00} [4].

There are several hesitations to implementing ΔE_{00} for the calculation of color differences in a new color rendering metric. The calculation of ΔE_{00} is considerably more complicated than ΔE^*_{ab}. Further, the use of ΔE_{00} is only recommended when ΔE^*_{ab} is less than five. For the range of color differences typical in color rendering, the use of both methods would then be required. If the new metric considers hue shifts and chroma shifts differently, as does the saturation factor of the proposed Color Quality Scale (CQS) [5], additional computational complexity arises in how to properly compute these shifts, as ΔE_{00} includes an interactive term between chroma and hue differences. Longevity is also an important concern [6]. Care should be taken to minimize the probability any one component of the new color rendering metric would become obsolete well before the others.

Effect of ΔE_{00} on color rendering calculations

Computations were performed to characterize the changes in calculated color differences for typical color rendering samples and lamps (fluorescents and LED models) that would be observed when ΔE_{00} was implemented instead of ΔE^*_{ab}. Two sample sets were used in the example presented here: the eight samples used in the calculation of R_a in the CRI [1] (low-moderate chroma) and the 15 samples proposed for use in the CQS [5] (high chroma). The calculation of ΔE_{00} was performed with the Excel spreadsheet provided by Sharma, Wu, and Dalal [7]. In the calculation of ΔE_{00}, when ΔE^*_{ab} was five or greater, its value was used; when less than five, ΔE_{00} was used.

Though both negative and positive changes were found when color differences of individual samples were calculated with ΔE_{00} rather than ΔE^*_{ab}, the mean of the color differences for each sample set (eight CRI, 15 CQS samples) was smaller when calculated with ΔE_{00} for all lamps presented here. Figure 1 shows the mean calculated color differences for a group of sources for each sample set, the eight CRI samples in the top panel and the 15 CQS samples in the bottom panel. The first three sources are typical fluorescent lamps and the remaining four sources are RGB white LED models (peak wavelengths indicated in parentheses). The white and grey bars show the color differences calculated by ΔE^*_{ab} and ΔE_{00}, respectively.

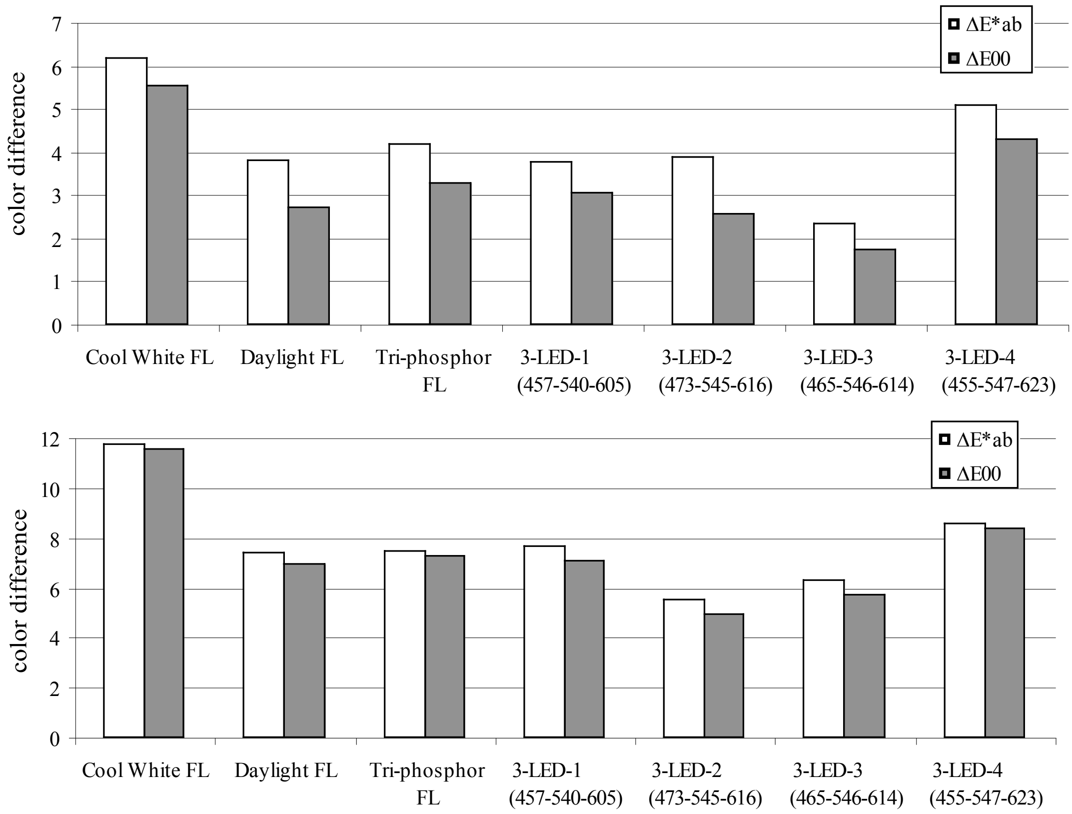

Figure 1. Calculated color differences for the eight CRI samples (top panel) and 15 CQS samples (bottom panel) when ΔE^*_{ab} is implemented (white bars) and when ΔE_{00} is implemented (grey bars).

The overall influence of ΔE_{00} is smaller for the 15 high-chroma CQS samples. This is expected, since only small color differences are calculated by ΔE_{00}, and samples higher in chroma tend to have overall higher color differences. Differences in CQS scores caused by implementing ΔE_{00} will be presented. Several aspects of the CQS are shown to reduce the effects of implementing ΔE_{00}, including its use of samples of high chroma and its application of root-mean square instead of averaging of individual samples' color differences.

References

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