International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

1 Colour Quality of Light Sources Related to Perception and Preference

1.1 Description of research

With the development of new lighting technologies, LED light sources are increasingly used for general lighting. These light sources are creating diversity in light spectra and imposing new challenges in assessing their colour quality. While a new colour fidelity index has been developed in CIE (CIE 224:2017) toward future update of the CIE Colour Rendering Index (CRI), a colour fidelity index alone will not be sufficient to assess the overall colour quality of light sources. Scores of a colour fidelity index do not always agree with perceived colour rendering experienced by end users.

The overall objective of the research topic is to develop indices for colour quality other than colour fidelity, especially those related to general colour preference, which is the perceived or subjective judgement of colour rendering (e.g. for naturalness). It is known that chroma saturation (gamut area) or shift of chromaticity from the Planckian locus has strong effects on perceived colour rendering or preference, but such effects are not measured with a colour fidelity index, and some preferred lights are penalized by a colour fidelity index such as the general colour rendering index, R_a. It seems there are general preferences in chroma saturation and chromaticity, but research data for such perception effects are still very limited. Data are lacking for various conditions, e.g. different hues, different objects viewed, different parameters (naturalness, preference), and long-term effects, in different applications, demographics (race, age, sex), or for different regions of the world. Much more research data are needed to be able to develop an index for perception-based colour quality. A whiteness index also needs to be investigated as a quality index to assess white lights, in order to resolve the problems associated with objects that contain optical brightening agents. Based on the research proposed here, CIE will define standard indices that can be used with a colour fidelity index, all of which will allow specifying or evaluating overall colour quality of lighting products.

1.2 Key research questions

- How can "preference" (or a model for colour quality perception) be clearly defined and assessed for the intended end use? It may also be affected by users' long term visual experience. How can it be addressed?
- Are the individual variations in such preferences too large to define general preference?
- Can the preference for chroma saturation and white light chromaticity be substantially different in different regions (or race of people) in the world?
- What are the relevant parameters to measure the subjective aspects of colour quality and the whiteness index?
- How to design an index to measure the whiteness perception of a light source? How to apply the surface whiteness indices for lighting application?

1.3 Justification of the need for the proposed research topic

There are many government regulations and voluntary programs to promote energy efficient lighting products. These regulations and specifications not only specify minimum luminous efficacy (lm/W) but also minimum values of the general colour rendering index, R_a, and ranges of white light chromaticity to ensure good colour quality as well as energy efficiency, as both are inter-related. Due to the nature of the CRI (or a colour fidelity index), many preferred lights with increased gamut are excluded when a minimum requirement is given, e.g. $R_a \geq 80$ or $R_a \geq 90$. The colour rendering index drives the manufacturers' choices of light sources to produce or develop in the future, and thus, has huge impact on the colour quality of lighting products that will be available for general consumers.

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Governments are using the CRI (in some cases both R_a and R_9) because only this index is currently available as international recommendation for the assessment of colour quality. In some applications, colour fidelity alone might be suitable, but it may be that in certain applications, colour preference should have a higher priority. Regulations and voluntary programs should be able to use both of these metrics or a combined index so that appropriate colour quality products can be recommended or allowed in different applications. Lights with large gamut areas (which might be more preferred) can be created with spectra containing narrowband peaks, e.g. RBG (Red, Blue, Green), RGBA (Red, Green, Blue, Amber), or hybrid types, while this can also be achieved by products with any spectra including phosphor white LEDs, having a chromaticity below the Planckian locus. Whiteness evaluation will also be very important in some applications. The use of the CRI (or a new colour fidelity index) alone may mislead or affect future development of new lighting technologies, thus it is critical and urgent to develop colour-preference-related indices and make them available as an international recommendation.

1.4 Related current activities in CIE

TC 1-91	New Methods for Evaluating the Colour Quality of White-Light Sources
TC 1-95	The Validity of the CIE Whiteness and Tint Equations
DR 1-61	Source Whiteness Metric
DR 1-62	Typical LED Spectra

1.5 Existing CIE publications

CIE 13.3:1995	Method of Measuring and Specifying Colour Rendering of Light Sources
CIE 015:2018	Colorimetry, 4th Edition (includes the CIE Whiteness Formula and SPDs of many traditional lamps including fluorescent lamps)
CIE 177:2007	Colour Rendering of White LED Light Sources
CIE 224:2017	CIE 2017 Colour Fidelity Index for accurate scientific use
October, 2015	CIE Position Statement on CRI and Colour Quality Metrics

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