Proposal for a Reportership in CIE Division 1
Colour border: luminous - blackish colours in white D65 surround

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For recent publications of the TUB group see: http://130.149.60.45/~farbmetrik/XY91FEN.html

Title

Colour border: luminous - blackish colours in white D65 surround

Terms of Reference

Study the literature which determines by psycho-physical and physiological experiments the colour border between luminous and blackish colours in white surrounds.

The report may include CIE tristimulus values *Y* as function of chromaticity *(x, y)* for D65. For applications the CIE data of optimal colours, for example with the complementary wavelength limits 475nm - 575nm (which have approximately maximum chroma C^*_{ab} (see *Hoffman*), and of the CIE-test colours no. 9 to 12 (approximately elementary hues according to CIE R1-47) of CIE 13.3 are important. The experimental data of *Hoffman* (1962), *Evans* (1974), and of zero blackness of the *Natural Colour System NCS* (1981), and physiological data of *Valberg* (2005) may be considered. For imaging application of displays the white surround D65 is preferred.

Background information from image technology

basic and mixed colors of standard colour displays (*sRGB* colour space)						
basic color or mixed color and name		CIE standard chromaticity *x*	*y*	CIE standard tristimulus value *X*	*Y*	*Z*
three additive basic colors:						
$O = R_d$	Orange red	0,6400	0,3300	43,03	22,19	2,02
$L = G_d$	Leaf green	0,2900	0,6000	34,16	70,68	12,96
$V = B_d$	Violet blue	0,1415	0,0482	17,82	7,13	93,87
three additive mixed colors:						
C	Cyan blue	0,2197	0,3288	51,98	77,81	106,83
M	Magenta red	0,3270	0,1576	60,85	29,32	95,89
Y	Yellow	0,4172	0,5019	77,19	92,87	14,98
D65	(White)	0,3127	0,3291	95,01	100,00	108,85

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Fig. 1: Display colours of *sRGB* display according to IEC 61966-2-1

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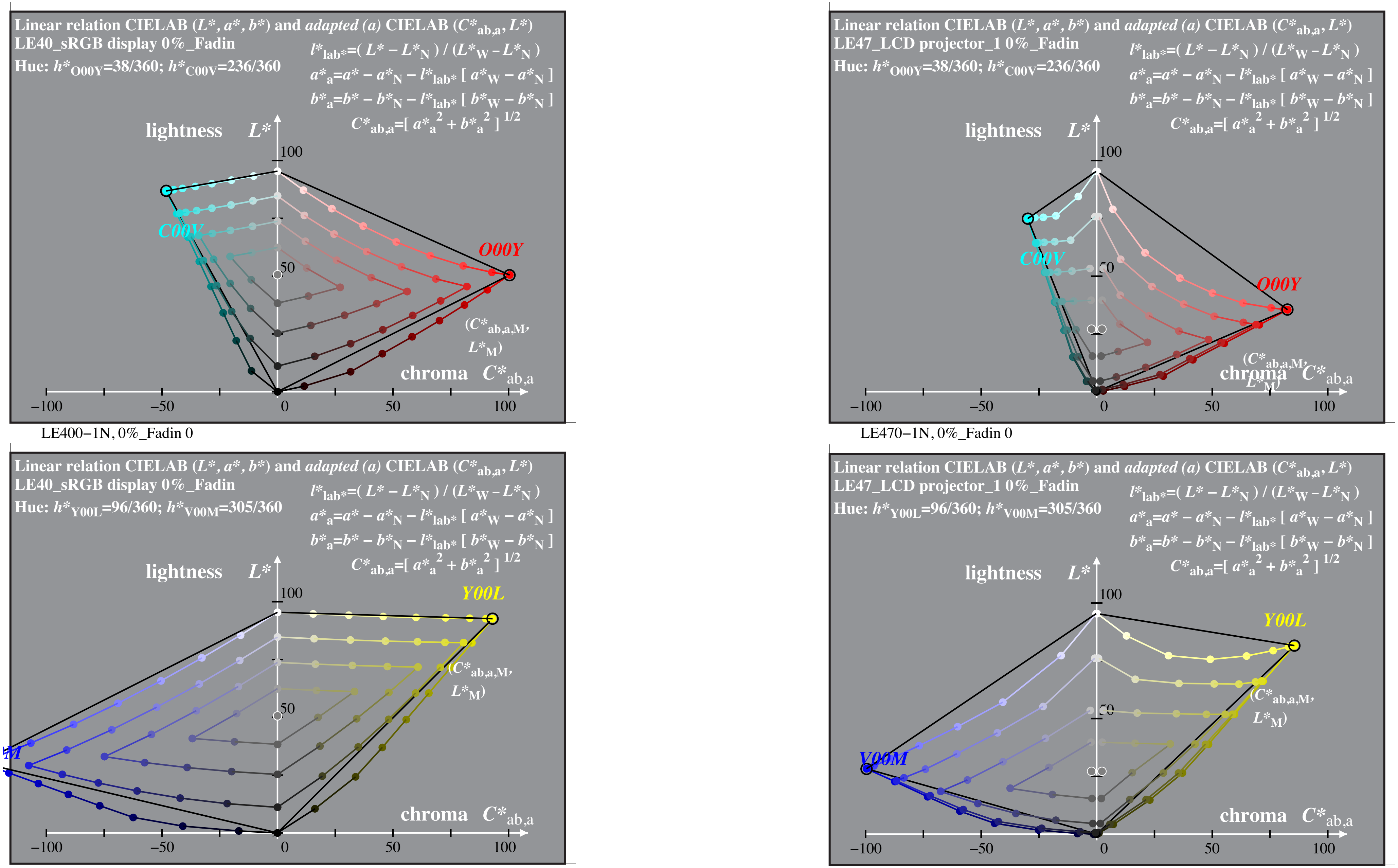

Fig. 2: CIELAB diagrams (C^*_{ab}, L^*) of *sRGB* display and *LCD* projector

New problems for image technology applications

For example the three tristimulus values Y of the device colours $Y_R+Y_G+Y_B$ do not any more mix to $Y_W=100$. This was the case for the standard *sRGB* display (compare the data $Y_R+Y_G+Y_B=100$ in Fig. 1).

Fig. 2 shows the CIELAB hue diagrams of the standard *sRGB* display *(left side)* and of a real projector *(right side)*. The lightness is normalized to equal values in all cases ($L^*=95$ according to ISO/IEC 15775).

All colours of the projector display *(right side)* are darker compared to the *sRGB* display. Therefore the appearance is more blackish (greyish) compared to the *sRGB* display. The sum of the three tristimulus values is less than 100 or $Y_R+Y_G+Y_B < Y_w$. The sum may be only 50%.

Similar all colours of some real *LED* and *OLED* displays are lighter compared to the standard *sRGB* display. Therefore the appearance is more luminous compared to the *sRGB* display.The sum of the three tristimulus values is larger than 100 or $Y_R+Y_G+Y_B > Y_w$. The sum may be 200%. For examples and simulations see Fig. 4 and 5.

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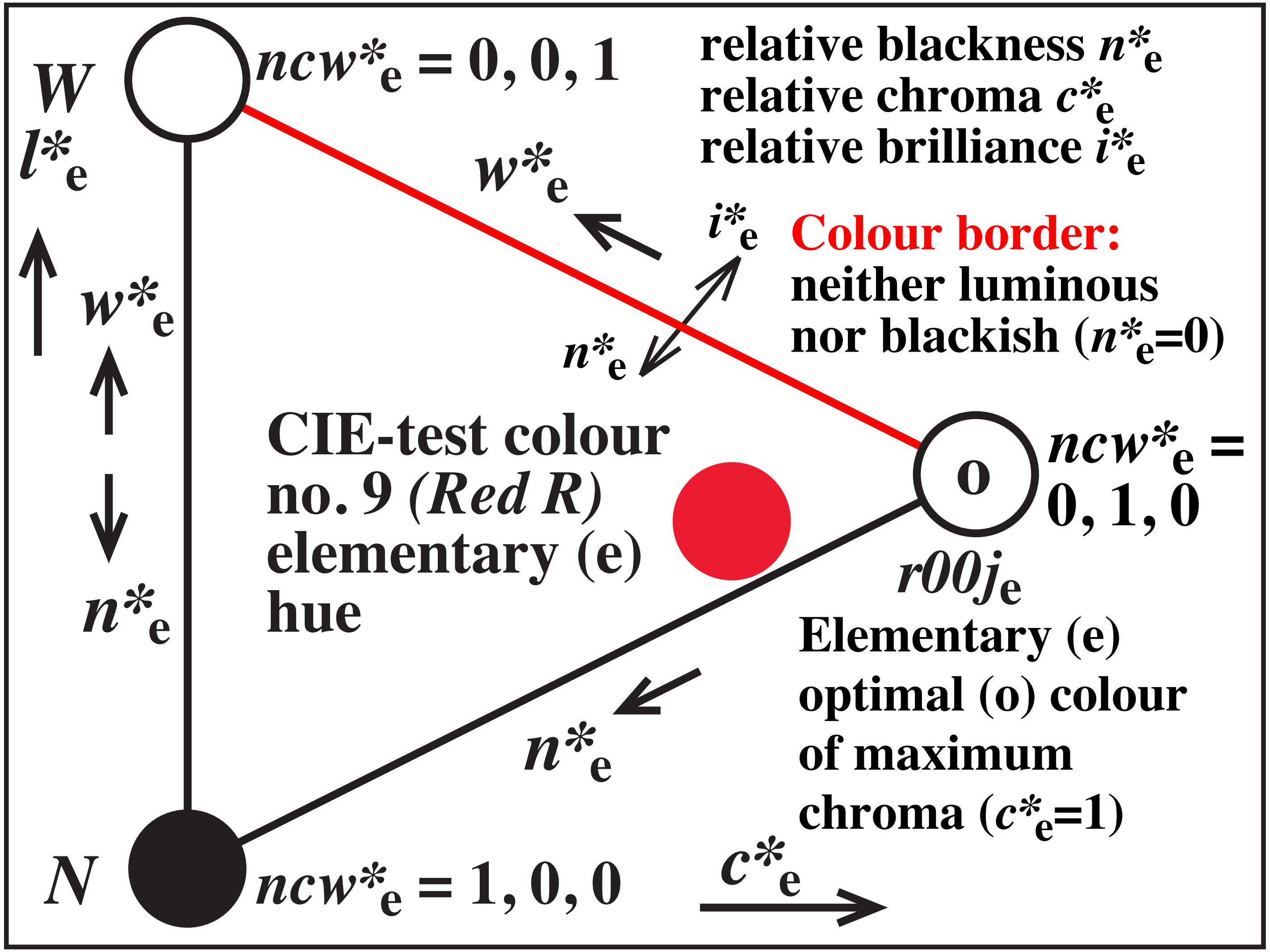

Fig. 3: Colour border: neither luminous nor blackish colours

For the elementary (e) hue the relative coordinates c^* and l^* are used.

The CIELAB relative lightness l^* and chroma c^* is related to n^* and i^*.

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Basic and mixed colors of standard sRGB and a special LED display						
basic color or mixed color and name		**CIE standard chromaticity** *x*	*y*	**CIE standard tristimulus value** *X*	*Y*	*Z*
sRGB display: three additive basic colors and White:						
$O = R_d$	Orange red	0,6400	0,3300	43,03	22,19	2,02
$L = G_d$	Leaf green	0,2900	0,6000	34,16	70,68	12,96
$V = B_d$	Violet blue	0,1415	0,0482	17,82	7,13	93,87
W	White	0,3127	0,3291	95,01	100,00	108,85
special LED display: three additive basic colors and White:						
$O = R_d$	Orange red	0,6400	0,3300	43,03+21%	22,19+21%	2,02+21%
$L = G_d$	Leaf green	0,2900	0,6000	34,16+21%	70,68+21%	12,96+21%
$V = B_d$	Violet blue	0,1415	0,0482	17,82+21%	7,13+21%	93,87+21%
W	White	0,3127	0,3291	95,01+0%	100,00+0%	108,85+0%

Assumption: Display of 142+30 cd/m^2 (=+21% compared to office standard)
rgb input data for D65 and internal 10%-change of *l**: 1,0 1,0 1,0 –> 0,9 0,9 0,9
rgb input data for Red and no internal display change: 1,0 0,0 0,0 = 1,0 0,0 0,0
Result: The office luminance 142 cd/m^2 for 500 lux on White paper is matched.
CIELAB lightness L^* and chroma C^*_{ab} of Red is 10% higher for the LED display.

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Fig. 4: Basic and mixed colours of the *sRGB* and a special *LED* display
If the display white is reduced from the relative lightness $l^* = 1$ to $l^* = 0{,}9$ and there is no change for *Red*, then both L^* and C^*_{ab} increase by 10%.

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Example files: Basic and mixed colors of a special LED display

basic color or mixed color and name		CIE standard chromaticity x	y	CIE standard tristimulus value X	Y	Z
special LED display: three additive basic colors and White:						
$O = R_d$	Orange red	0,6400	0,3300	43,03+44%	22,19+44%	2,02+44%
$L = G_d$	Leaf green	0,2900	0,6000	34,16+44%	70,68+44%	12,96+44%
$V = B_d$	Violet blue	0,1415	0,0482	17,82+44%	7,13+44%	93,87+44%
W	White	0,3127	0,3291	95,01+0%	100,00+0%	108,85+0%

Assumption: Display of 142+64 cd/m^2 (Y = +44% compared to office standard)
rgb input data for Red and no internal display change: 1,0 0,0 0,0 = 1,0 0,0 0,0
rgb input data for D65 and internal 20%-change of l^*: 1,0 1,0 1,0 –> 0,8 0,8 0,8
See example simulation files with 0, 5, 10, ..., 35% change and
white frame: http://130.149.60.45/~farbmetrik/LE52/LE52L0NP.PDF
grey frame: http://130.149.60.45/~farbmetrik/LE53/LE53L0NP.PDF
Compare for example samples 01b (White) and 01j (Orange red) on different pages

Result: Lightness L^* and chroma C^*_{ab} of Red is 20% higher for the LED display.
relative brilliance $i^* = l^* + 0{,}5\ c^*$ of Red is 30% higher for the LED display.
relative blackness $n^* = 1 - i^*$ of Red is 30% lower for the LED display.

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Fig. 5: Example Files: Basic and mixed colours of a special *LED* display
Both CIELAB lightness L^* and chroma C^*_{ab} of *Red* increase by 20%.
Relative brilliance i^* and relative blackness n^* change by 30%.

Goal of the Reportership

It is intended to search in the literature for the CIE tristimulus values *Y* as function of CIE chromaticity (*x,y*) of many colours at the colour border between neither luminous nor blackish.

Examples are given in book of *Evans* (1974) and in the *Swedish Natural Colour System NCS* (1981).

The optimal colours with complementary wavelength limits for D65, for example 475nm-575nn, 380nm-562nm, 493nm-780nm are approximately (see *Hoffmann* (1962)) the most chromatic of all possible optimal surface colours. They may define the border line luminous - blackish.

For imaging applications the tristimulus values *Y* at the border luminous - blackish are of importance for the four chromaticities *(x,y)* of the CIE-test colours no. 9 to 12 (compare the report CIE R1-47:2008).

For TC1-81 "Small Colour Differences" the tristimulus value *Y* at the border luminous - blackish may be the point of the largest discriminability $Y/\Delta Y$. This point may have the largest slope of the physiological signals (S-shape functions) shown in the next Fig. 6.

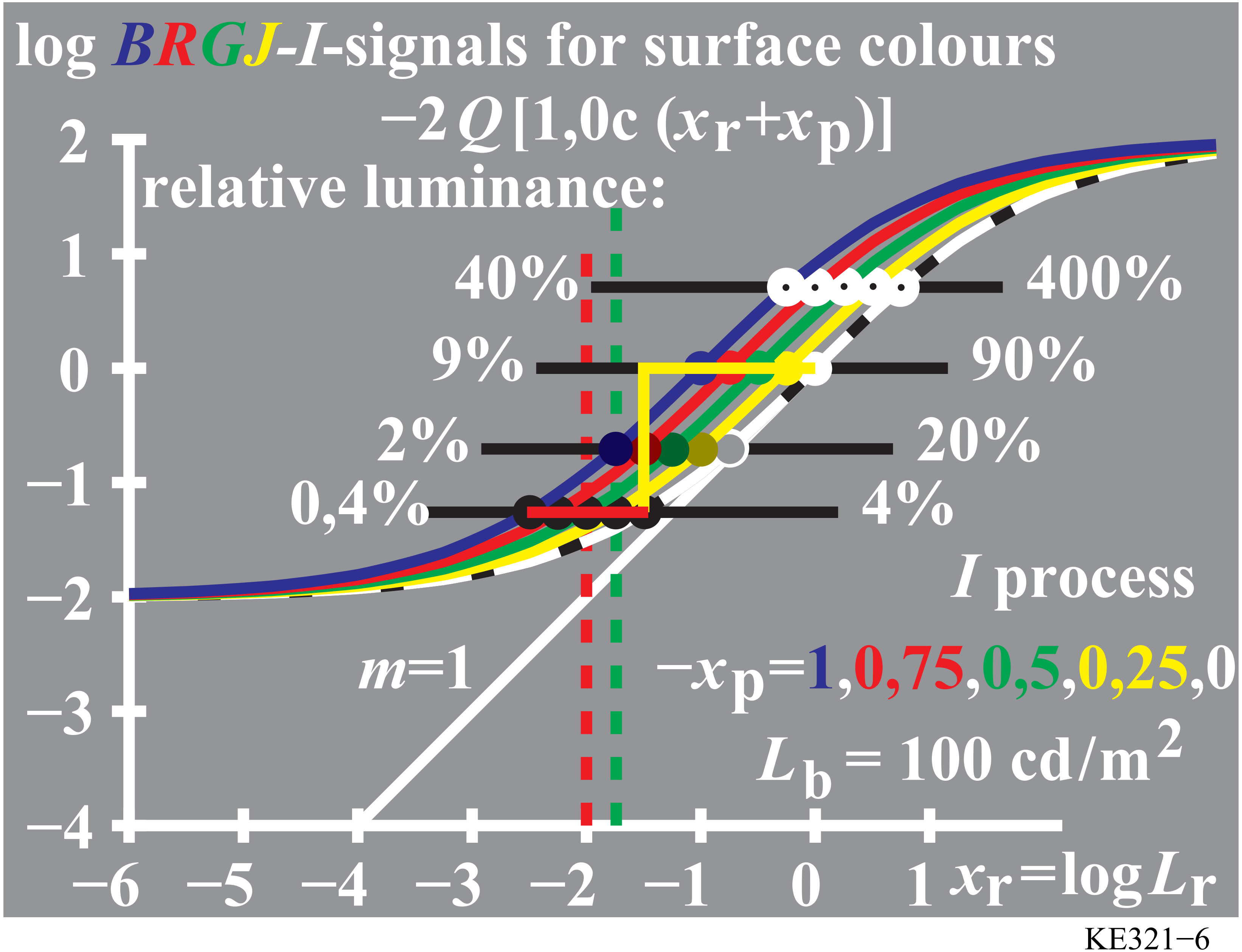

Fig. 6: Physiological *I*-signals of chromatic and achromatic colours.

According to Fig. 6 the relative luminance of Blue *B* is only 10% compared to White *W* (compare 7% in Fig. 1 for the *sRGB* display).

For TC1-69 “Colour Rendering of White Light Sources” the increase of CIELAB lightness L^*, chroma C^*_{ab}, relative lightness l^*, relative brilliance i^* for Red (and similar for Green) is of interest.

For example the spectral power of a 3-band light source is usually *reduced in the yellow region* near 575nm. This may increase the CIELAB lightness L^*, chroma C^*_{ab}, relative lightness l^*, and relative brilliance i^* by for example 15%. This is expected because the very less saturated yellow region is deleted. Therefore new reference samples, and a newer colour metric is possible for both lighting and image technology.

Literature:

Evans, R (1974), The perception of Color, Wiley, John & Sons, Incorporated, 250 pages

Hard, A. and Lars Sivik (1981), NCS - Natural Color System: A Swedish standard for color notation, Color Research and Application, no. 3

Hoffmann, K. D. and P. Weisenhorn (1962), Zur Ermittlung der Farben groesster Buntkraft (Determination of colors of maximum chroma), Experientia 18, 525, Birkhaeuser, Basel, 1-14

Valberg, A. (2005), Light, Vision, Color, Wiley, ISBN 0 470 84903 7, 462 pages