Philipp Kittelmann

Topic of the thesis:

Visual Assessment of Small and Large Colour Differences and Characterisation with Colour Differences Formulas

Structure

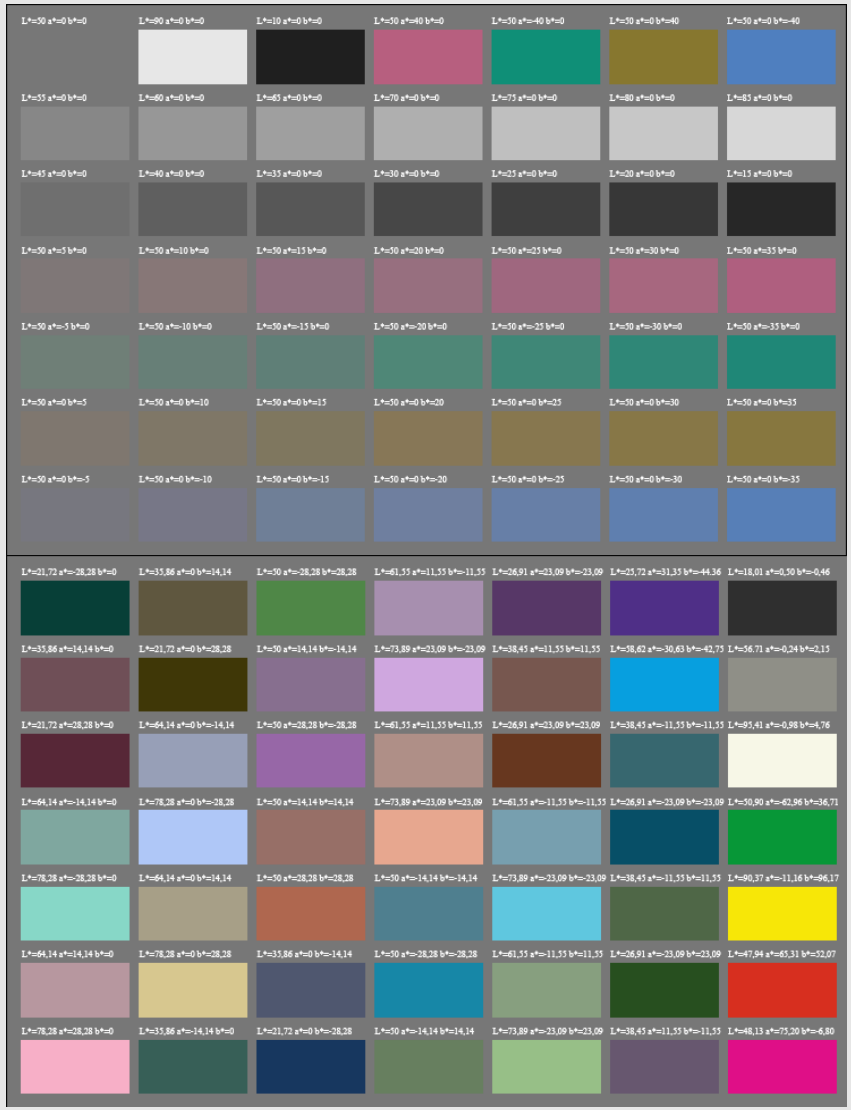
- **Research Statistics**
- **Colour Thresholds**
- **Large Colour Differences**

Research Statistics

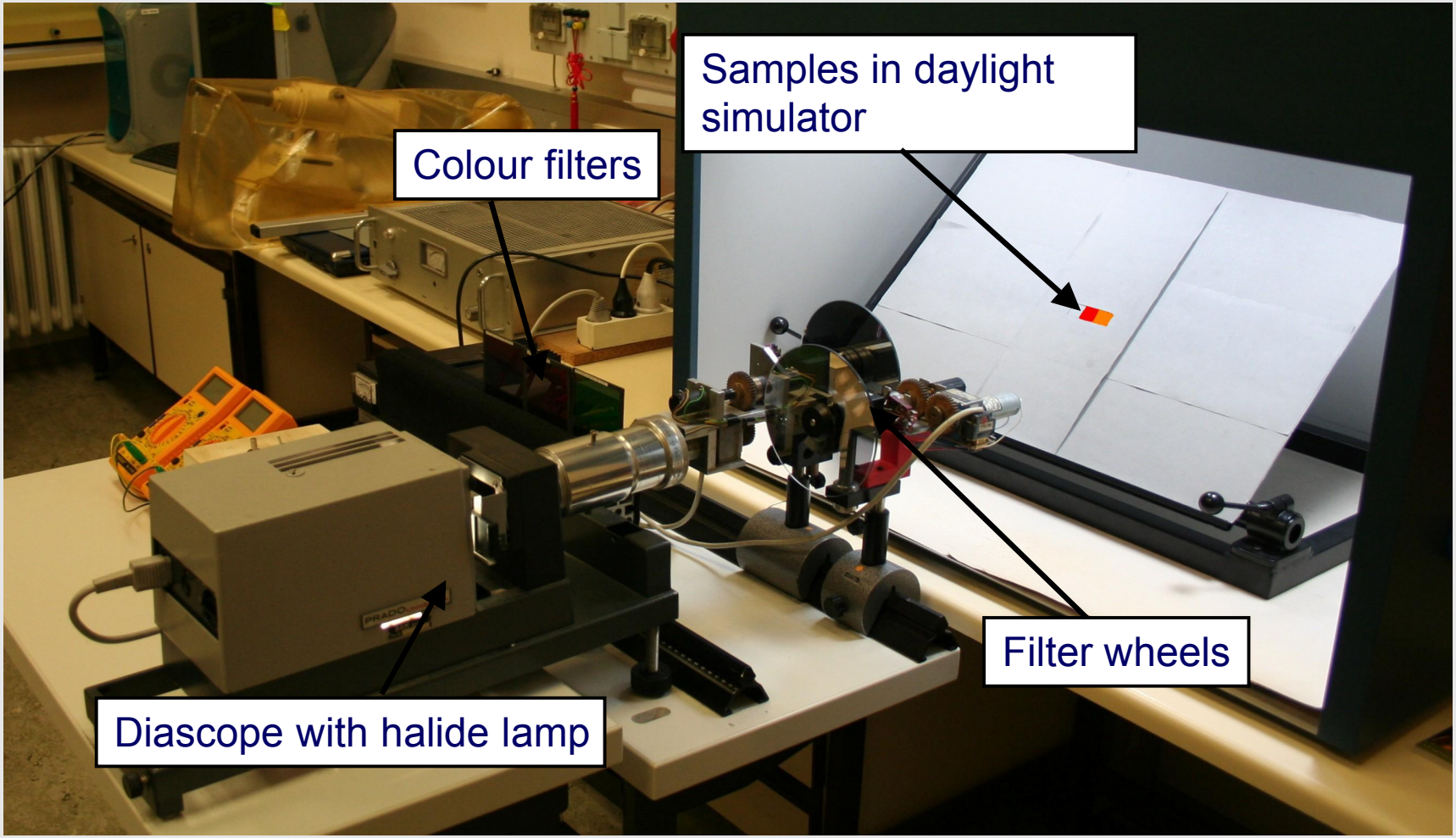
- **The research was conducted with 40 test persons.**
- **The colour blindness of all 40 test person was checked.**
- **17 women und 23 men attended the research.**
- **The average age was 24.8 years and only 6 persons were older than 30 years.**

Colour Threshold Research

- **98 colour samples and 4 colour changes for each samples:**
  - **Without a filter (lightness)**
  - **With a red filter (colour-matching function $\bar{x}$)**
  - **With a green filter (colour-matching function $\bar{y}$)**
  - **With a blue filter (colour-matching function $\bar{z}$)**

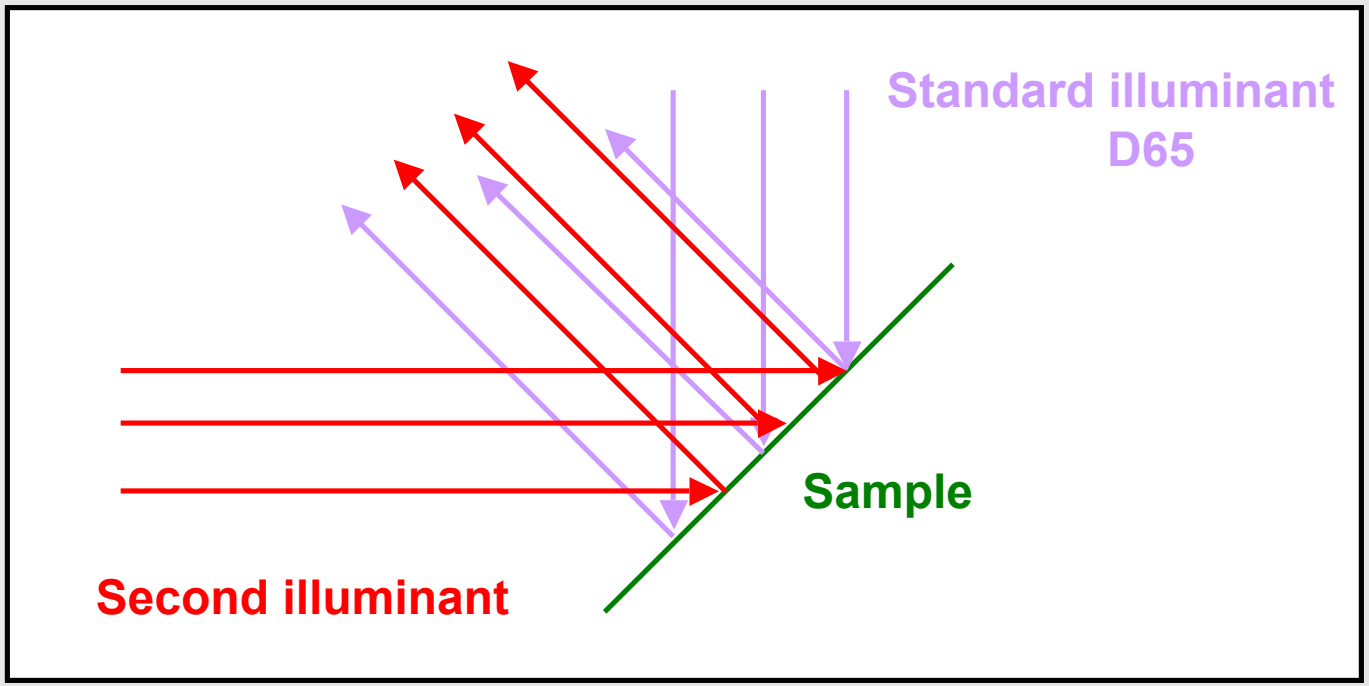


Experimental Set-up



Principle of the Threshold Generation

- **The colour thresholds are generated by "addition" of a second illuminant to the D65 standard illuminant.**



$$R_{neu}(\lambda) = \frac{S_{D65}(\lambda) + S_2(\lambda)}{S_{D65}(\lambda)} R_{alt}(\lambda)$$

Quotient Θ

$$\Theta = \frac{\Delta E^*_{\min}}{\Delta E^*_{\max}}$$

- ΔE^*_{min} is the smallest colour difference of a colour threshold for a sample
- ΔE^*_{max} is the largest colour difference of a colour threshold for a sample
- This quotient Θ is calculated for every sample and the average is generated
- A quotient near 1 is better than a quotient near 0

STRESS Value *S*

$$S = 100 \cdot \sqrt{\frac{\sum \left(\Delta E_i - F \cdot \Delta V_i\right)^2}{\sum \Delta E_i^2}} \qquad F = \frac{\sum \Delta E_i \cdot \Delta V_i}{\sum \Delta V_i^2}$$

- ΔE^*_i are the colour differences of a colour threshold for a sample
- ΔV_i will be set 1 because of all colour thresholds the colour difference to the reference sample should be the same
- This STRESS value *S* is calculated for every sample and the average is generated
- A STRESS value near 0 is better than a quotient near 100

Comparison of some Colour Difference Formulas

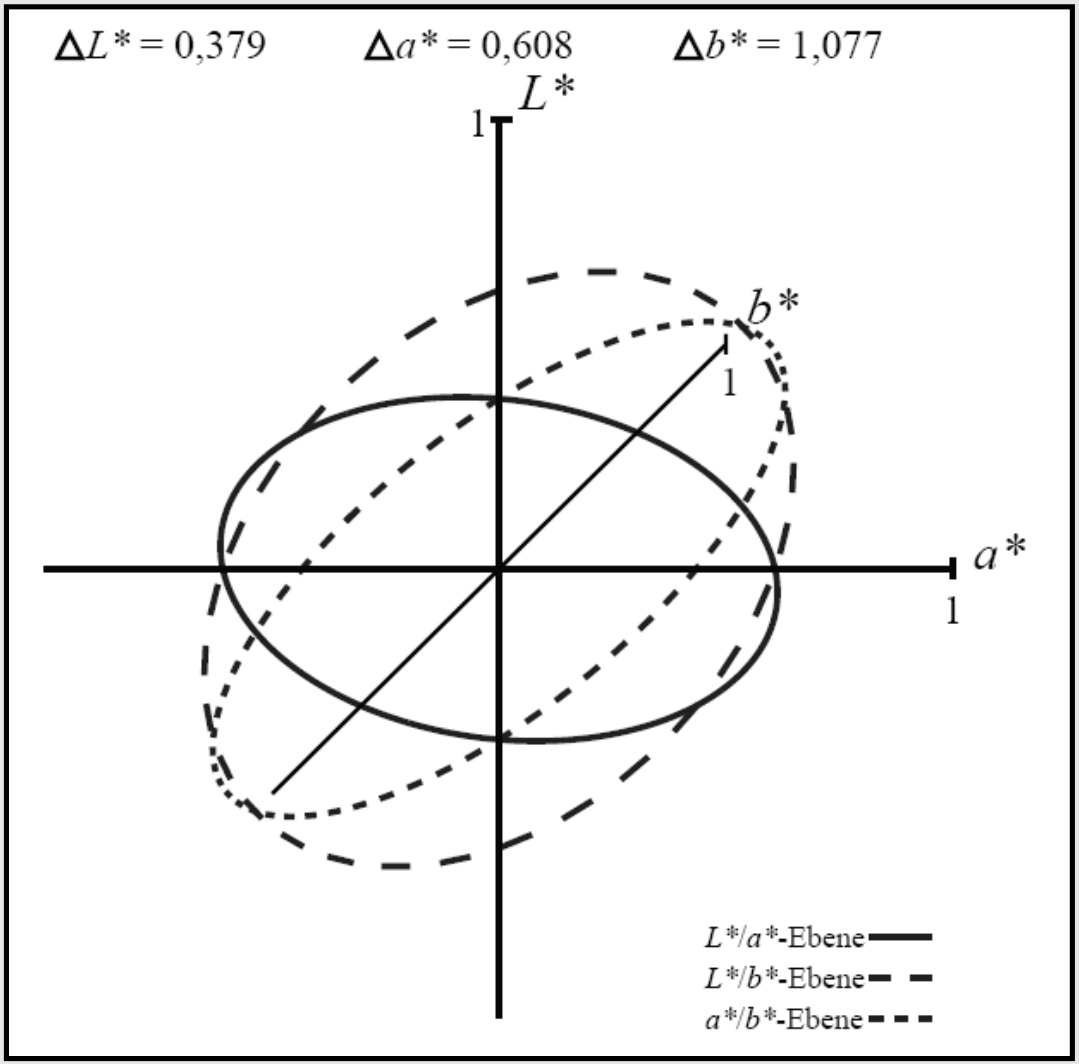
	$\Theta_{100,s}$	$S_{100,s}$	Parameter				$\Theta_{100,p}$	$S_{100,p}$
CIELAB	29,800	54,587	α	0,515	β	0,153	60,100	80,200
CMC	32,600	56,937	l	0,418	c	2,417	46,200	71,436
CIE94	35,600	58,674	K_C	4,432	K_H	2,025	44,600	71,371
CIEDE2000	34,600	60,668	K_C	2,953	K_H	3,179	49,400	74,041
DIN99	44,500	67,674	k_E	1,756	k_{CH}	1,950	53,000	76,549
DIN99o	34,700	59,367	k_E	0,776	k_{CH}	3,439	48,400	74,559
LABJNDS	29,400	59,621	a_0	2,519	b_0	0,609	62,700	81,237

$$\Theta_{100} = 100 \cdot \Theta \qquad S_{100} = 100 - S$$

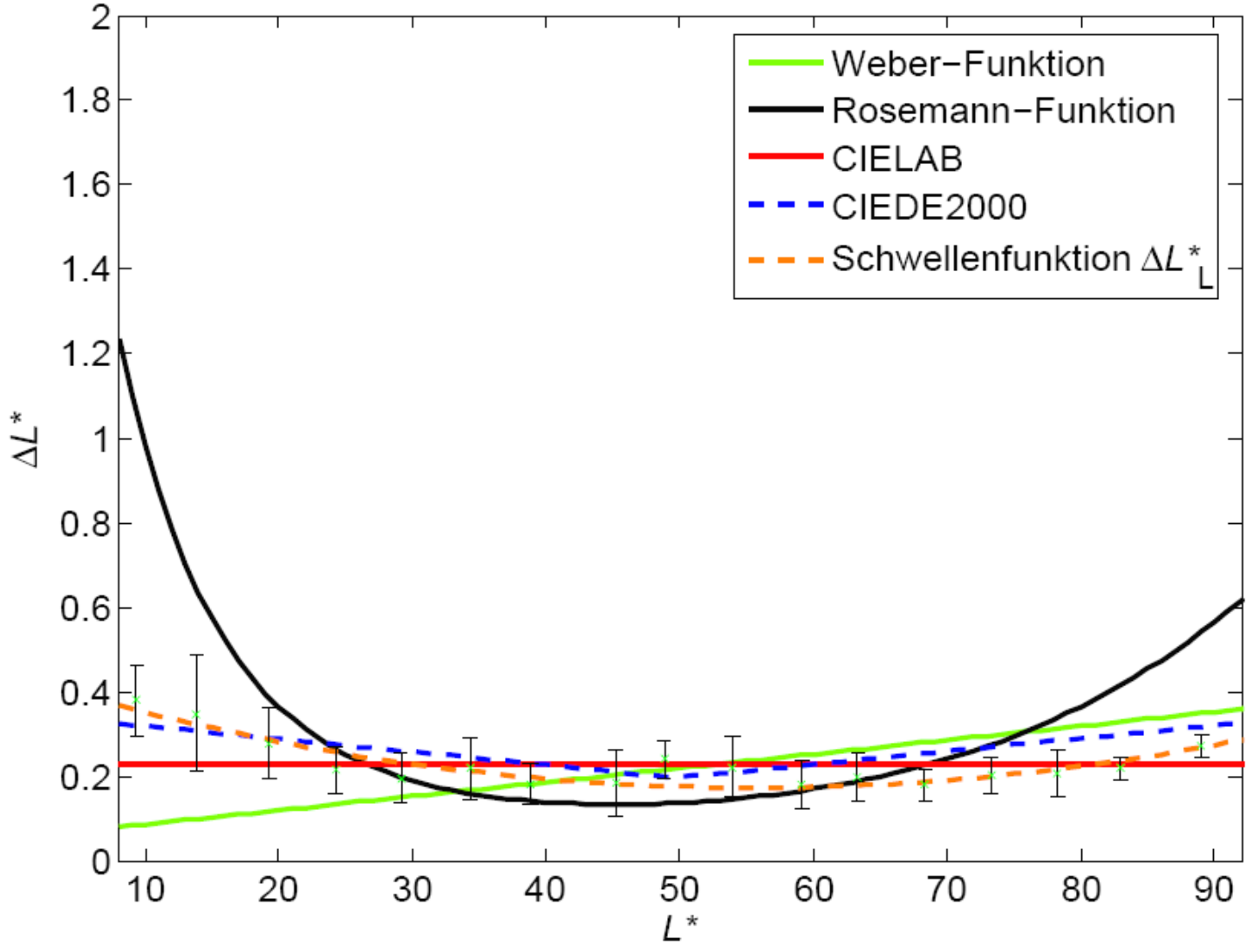
- The values Θ_{100} and S_{100} are established for better comparison. Both values are better if the are near 100.

Threshold Analysis

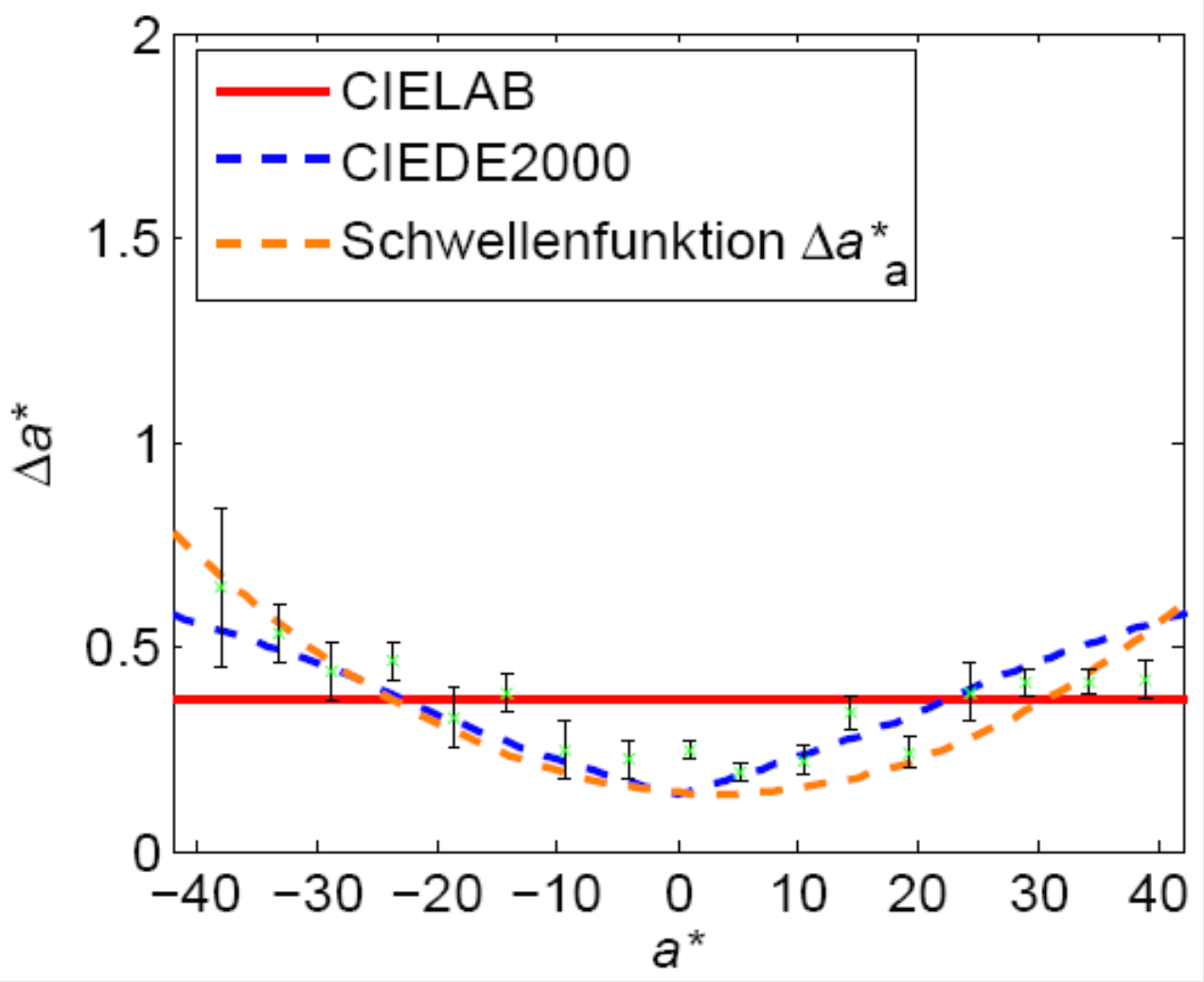
- **Out of the four colour differences of the colour threshold a ellipsoid is calculated.**
- **The values of the ellipsoid expansion in direction of the CIELAB values are taken.**



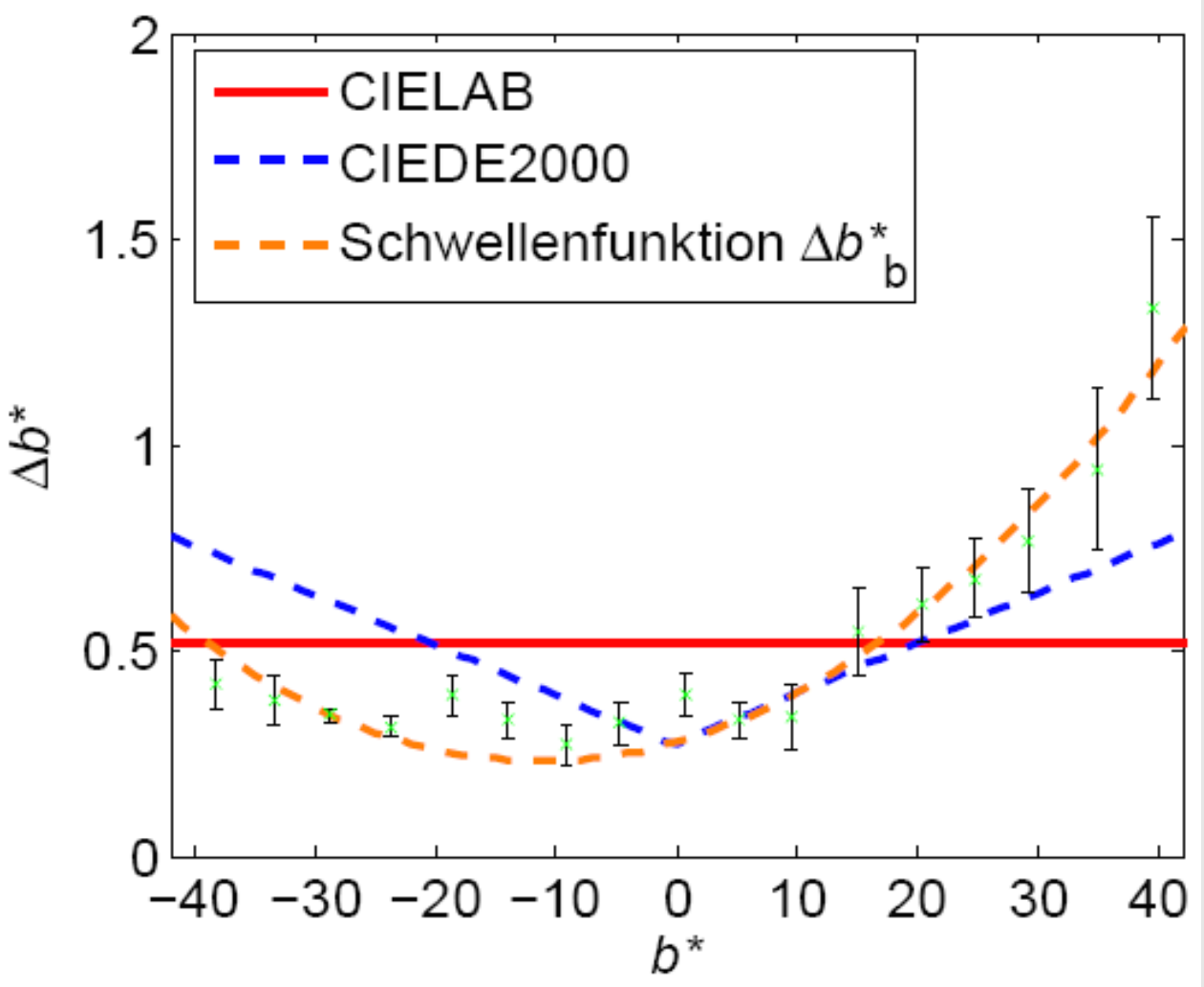
ΔL^* as function of the Lightness L^*



Δa^* as function of the red green value a^*



Δb^* as function of the yellow blue value b^*



Summary Colour Thresholds

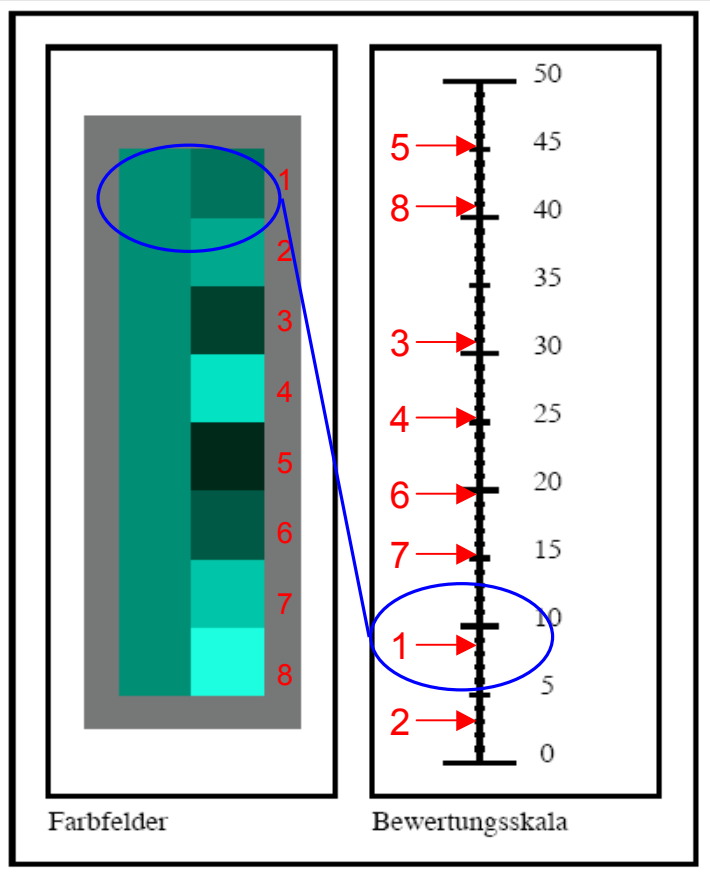
- **CIEDE2000 is better than CIELAB (15 % on the STRESS value *S*)**
- **DIN99 is best (22 % than CIEDE2000 on the STRESS value *S*)**
- **All colour differnce formulas improve if their parameter are fit to the viewing conditions**
- **The yellow blue differences Δb^* is for colour threshold larger than the red green differences Δa^* or the lightness differences ΔL^***

Research on Large Colour Differences

- **Colour difference with ΔE^*_{ab} larger than 10**
- **9 reference colours**
- **6 colour rows with 8 colour changes and one colour row with 16 colour chnages for each reference colour**
- **Viewing conditions:**
  - **D65 standard illuminant**
  - **0°/45° geometrie**
  - **CIE 1931 standard colorimetric observer**

Visual Assessment of the Large Colour Differences

- **The test persons assess the colour differences on a scale from 0 to 50**
- **The reference colour on the left is compared to the colours on the right**
- **Espacially the relationship between the colour difference is important**



Analysis of the Large Colour Differences

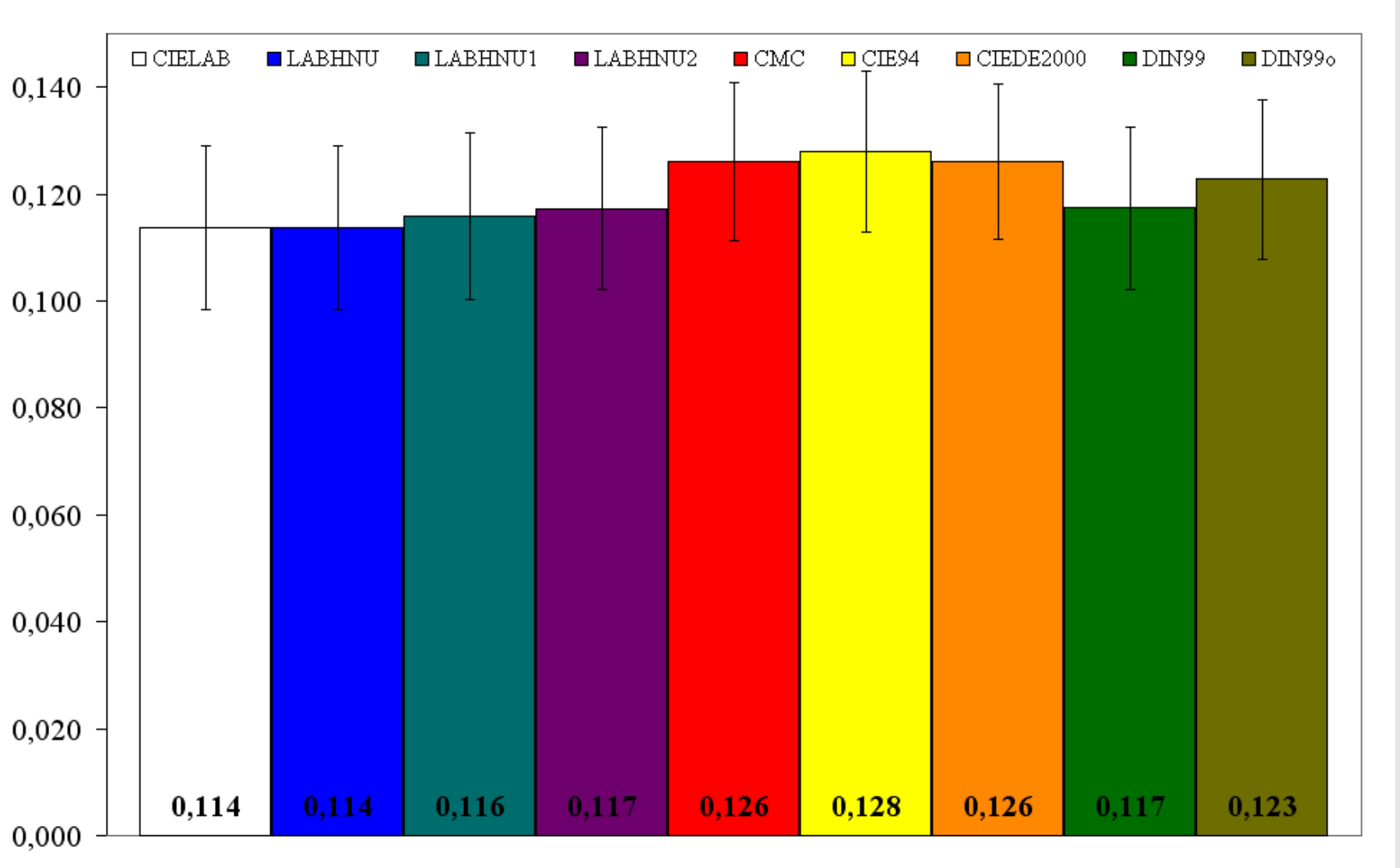
- **The visual assessment and the colour difference are scaled on value between 0 and 1**
- **The difference between the scaled assessments and the scaled colour differences show the correlation between them**

$$\Gamma E^*_i = \frac{\Delta E^*_i}{\Delta E^*_{\max}}$$

$$\Gamma B_i = \frac{B_i}{B_{\max}}$$

$$\omega E^* = \left| \Gamma B - \Gamma E^* \right|$$

Comparison of some Colour Difference Formulas



Summary Large Colour Differences

- **CIELAB shows best result but is not significant better than the other colour difference formulas**
- **The correlation between visual assessment and the calculated colour difference varies for the different reference colour and colour changes**
- **No statement possible which parameters generates this variations**

END

Thanks for your attention