Lux Junior 2017

Investigation of color matching functions for prediction of perception of luminous color differences depending on age and luminous color in the surrounding

Untersuchung von Spektralwertfunktionen für die Beschreibung der Wahrnehmung von Lichtfarbenunterschieden in Abhängigkeit von Alter und Umfeldlichtfarbe

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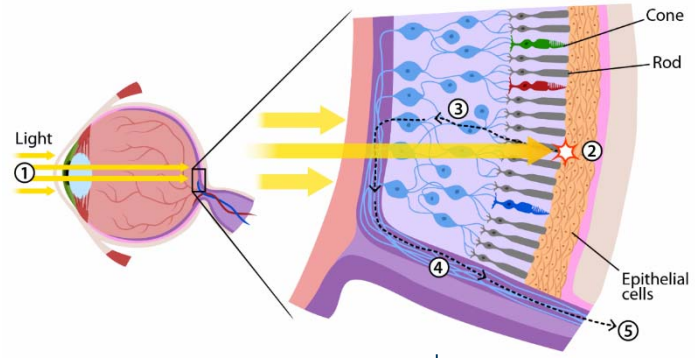
10.09.2017

1 Introduction – Why did we do this?

1 Introduction

Image Copyrights:
Eye: askabilogist.asu.edu
LED: osram.com

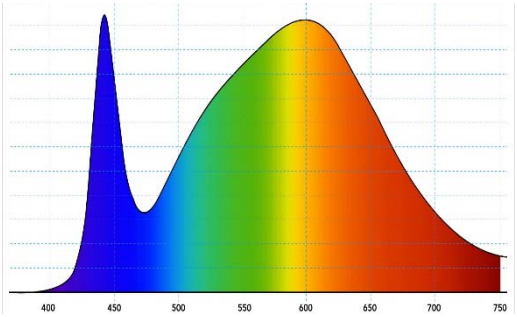
What are Color Matching Functions (CMFs)?



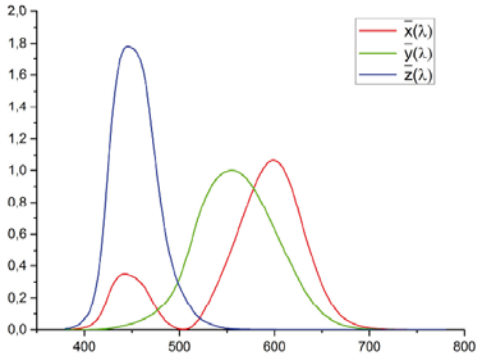
Color Effect

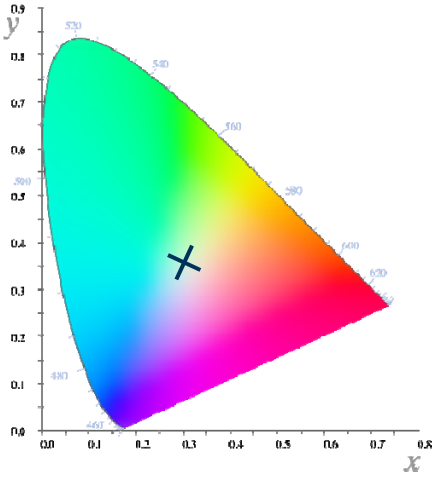
Color Coordinate

Light Spectrum



Color Matching Functions

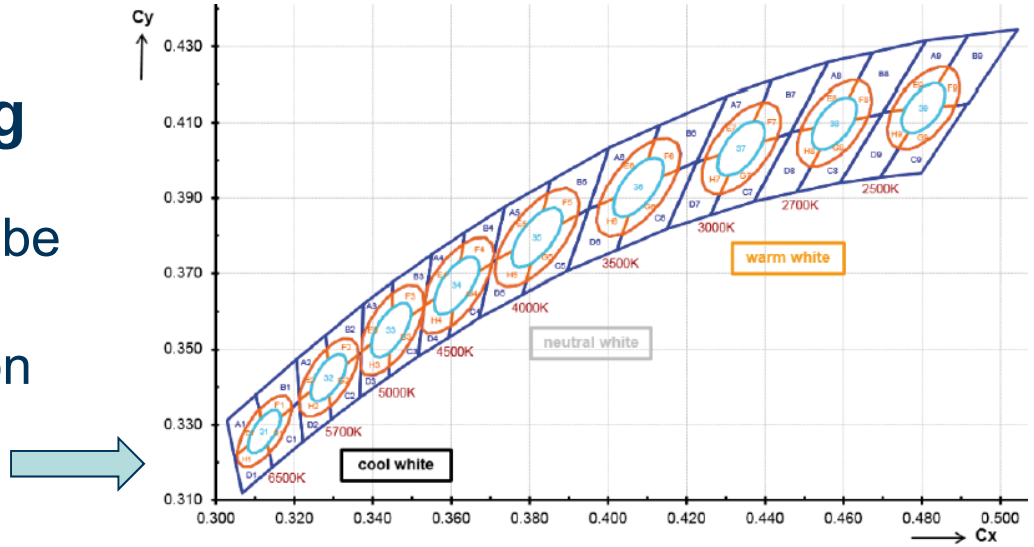




1 Introduction

Problem 1: LED-Binning

LED production process can‘t be handled precise enough:
Binning (=sorting) of production necessary according to color coordinate



[osram.com]

Binning is based on the insights of MacAdam (1940s) and the standardized color matching functions (CMF) CIE1931:

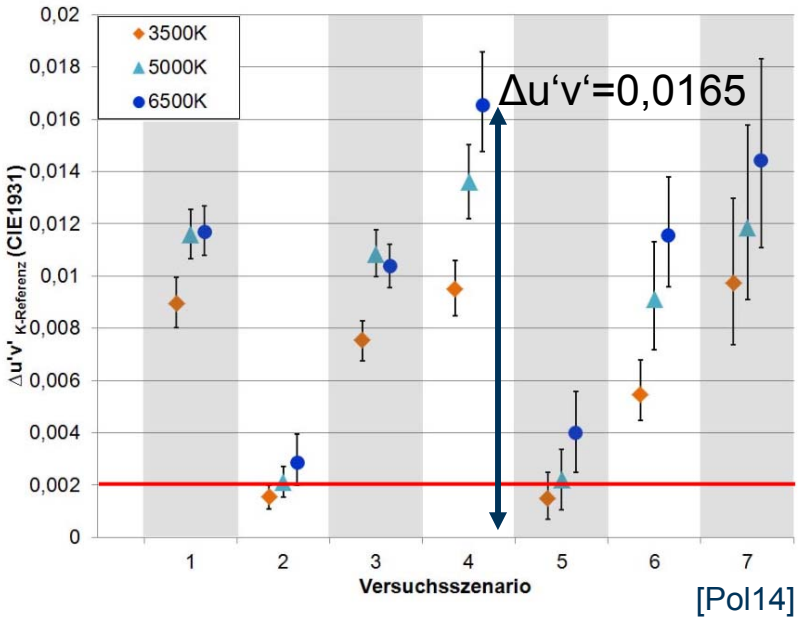
Points of criticism:

- Difference in lighting technology then and now
- Low number of subjects
- Testing conditions do not match current applications
- ➢ Further validity of this standard is questionable

1 Einführung

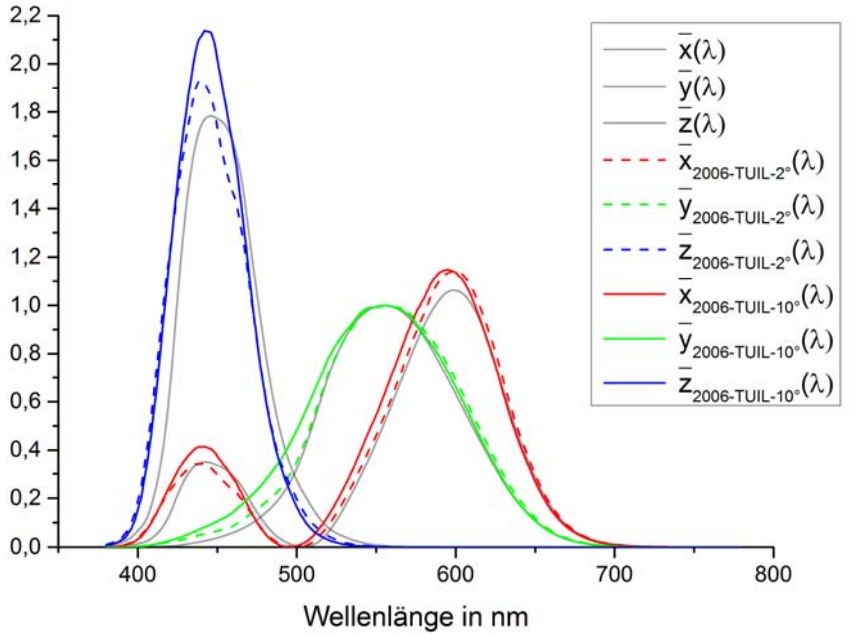
Problem 2: Color Space Failures

Research from POLSTER:
visual similar lights show partly high color coordinates distance with CIE1931 CMFs



[Pol14]

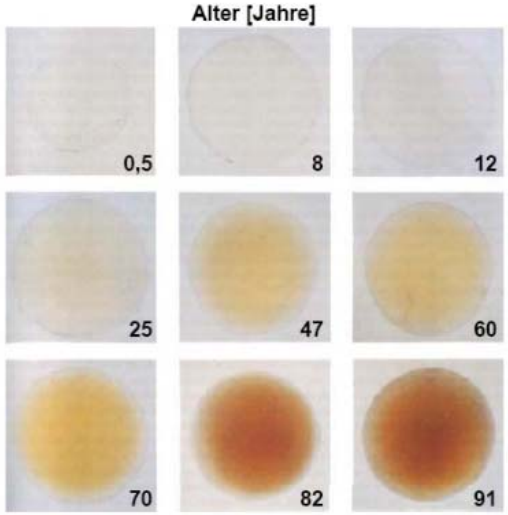
Development of adjusted CMFs:
2006-TUIL-2° bzw. 2006-TUIL-10°



1 Introduction

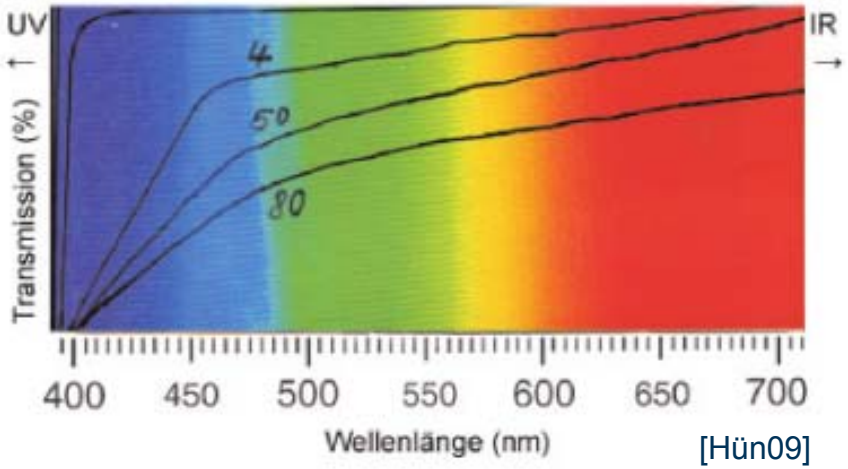
Problem 3: Age-dependent yellowing of eye lens

Age-dependent yellowing of eye lense



[Ler80]

Age-dependent transmittance of eye lens



[Hün09]

Calculation of age-dependent CMFs described in:

CIE170-1:2006 und CIE170-2:2015

2 Study – What did we do?

2 Study

Method of Study

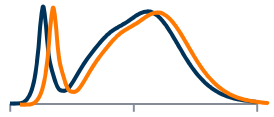
>60 years <35 years

LED1 LED2

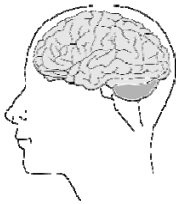
lighted rating areas

lighted surrounding

Spectra

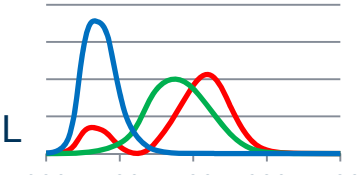


color processing in brain



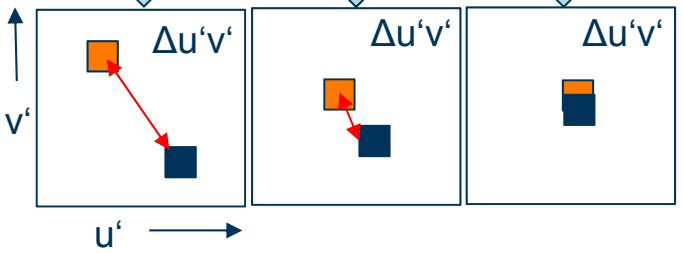
Color Matching Functions

- CIE1931
- CIE2006
- 2006-TUIL



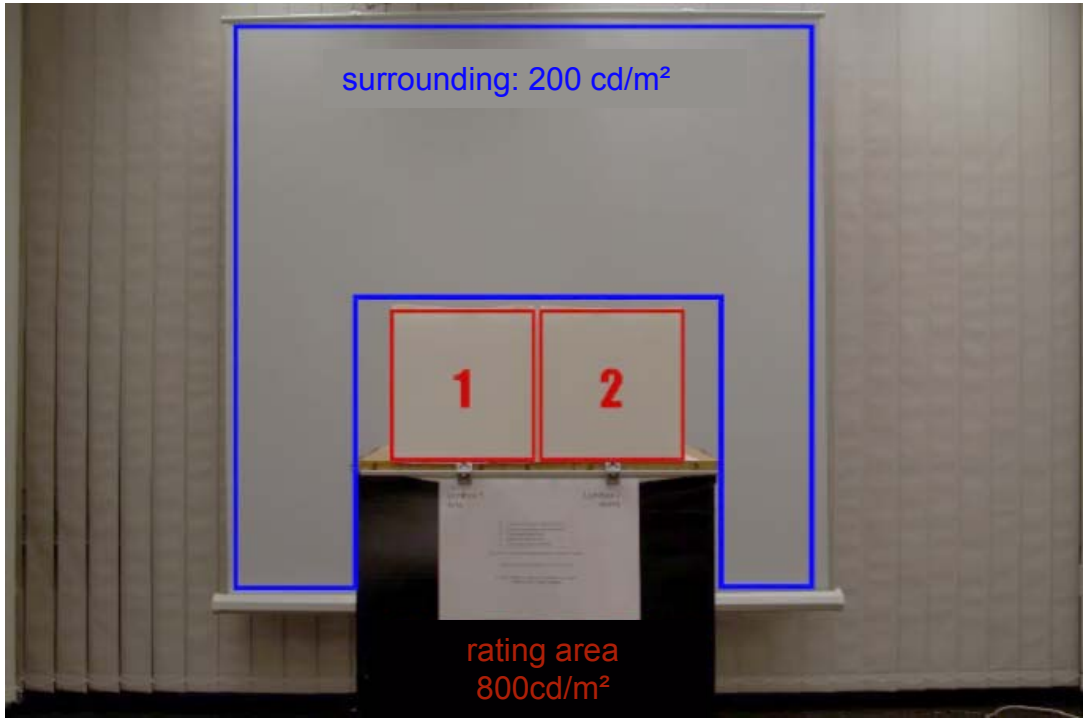
0	no noticeable color difference
1	
2	just noticeable color difference
3	
4	small color difference
5	
6	big color difference
7	
8	very big color difference

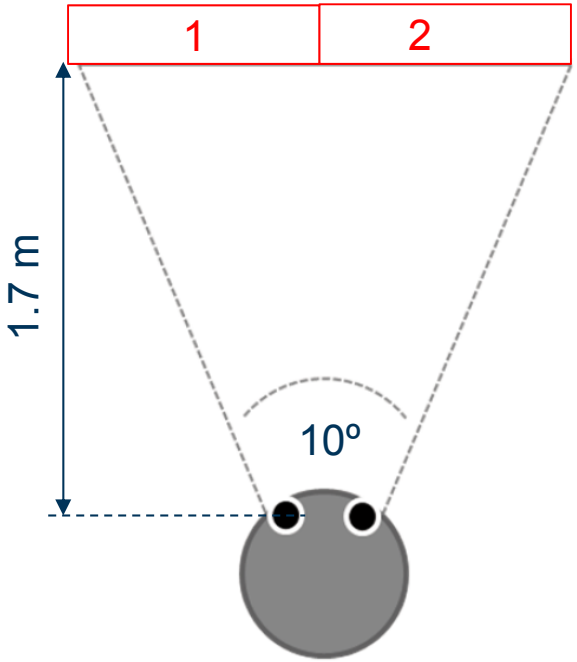
correlation?



2 Study

Setup of Study



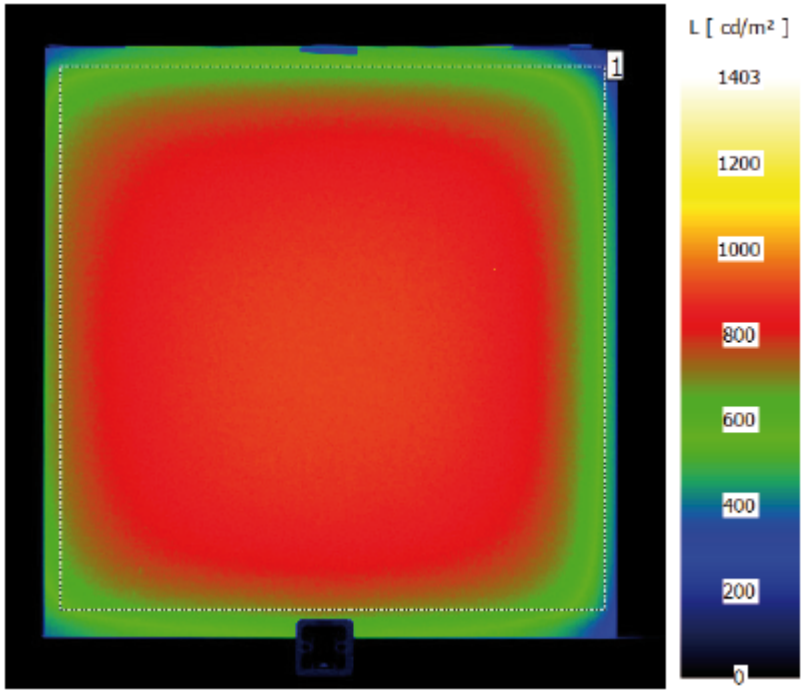


- rating area: 30 cm x 30 cm each
- 10 different LED spectra (CCT=3.500K)
- distance subject to rating area: 1,7m (-> field size: 10°)

2 Study

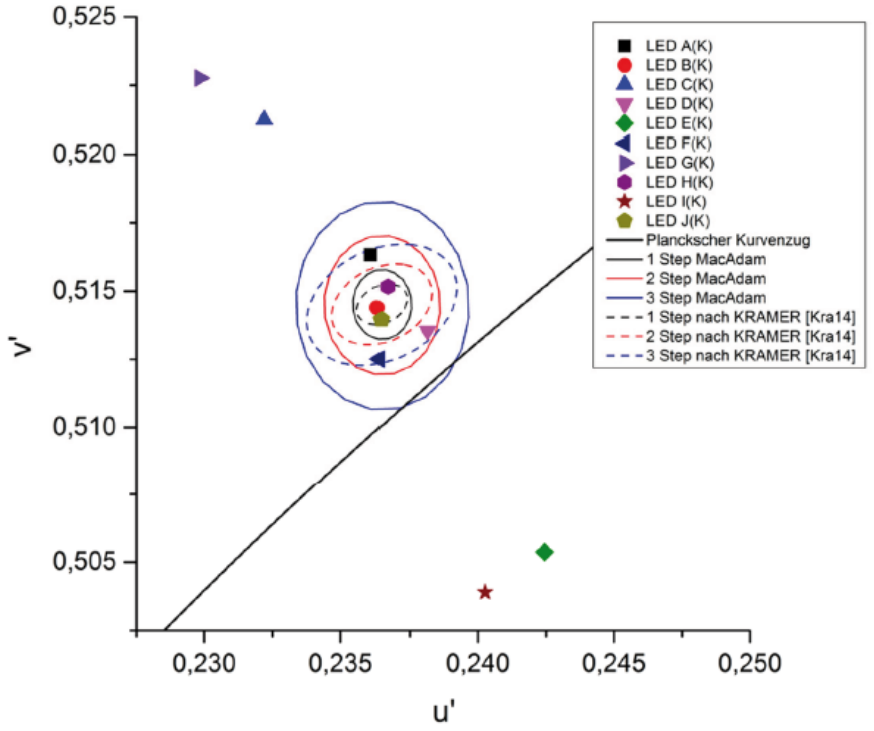
Measurement of Setup

Luminance of Lightbox



L_{min}	L_{max}	$\bar{L}$	σ	g_2
650 cd/m²	890 cd/m²	800 cd/m²	90 cd/m²	73%

Color coordinates of the 10 lightboxes



2 Study

Selection of Test Combinations

- Calculation of color coordinate distance for various CMFs: $\Delta u'v' = \sqrt{(u_1 - u_2)^2 + (v_1 - v_2)^2}$
  - Current standard: **CIE1931** und **CIE1964**
  - Newest recommendation of CIE: **CIE2006-2°** and **10°** acc. to CIE170-2:2015
  - Development of POLSTER: **2006-TUIL-2°** and **10°**
  - Age-adjusted CMFs acc. to CIE170-1:2006 (**CIE2006-10°-A70**, **2006-TUIL-10°-A70**)
- Selection of suitable test combinations

small: Δu'v' < 0,0021	medium	big: Δu'v' > 0,0040

CIE1931	CIE2006 2°	2006-TUIL-2°	CIE1964	CIE2006 10°	CIE2006 10° A60	2006-TUIL-10°	2006-TUIL-10° A60
0,0034	0,0025	0,0053	0,0002	0,0004	0,0036	0,0046	0,0007

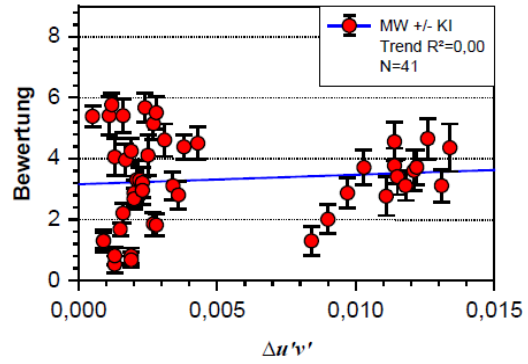
⇨ 23 different test combinations

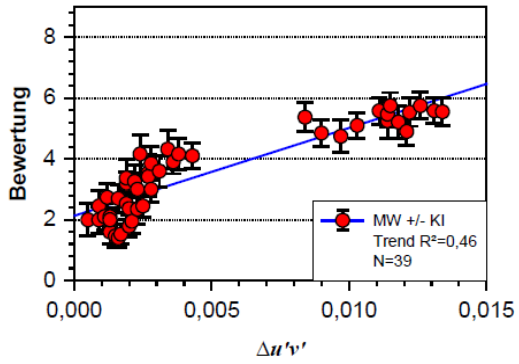
3 Result – What did we find out?

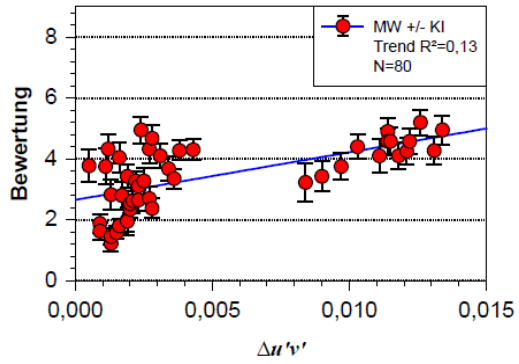
3 Result

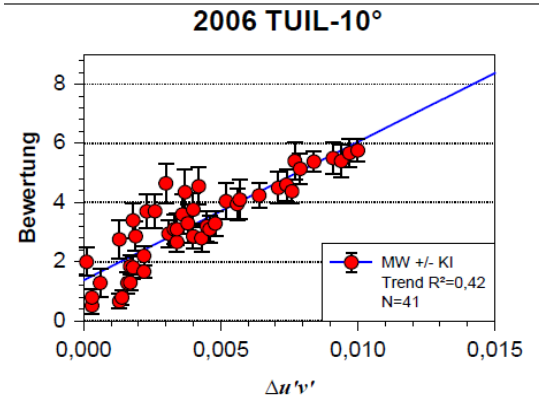
Part 1: Analysis of Age and Color Matching Function

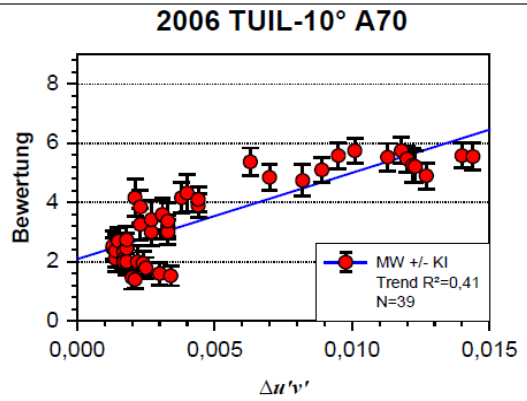
Young subjects (<35 years, N=41)	Older subjects (>60 years, N=39)	All subjects N=80
CIE 1931	CIE 1931	CIE 1931
2006 TUIL-10°	2006 TUIL-10° A70	2006TUIL -10°

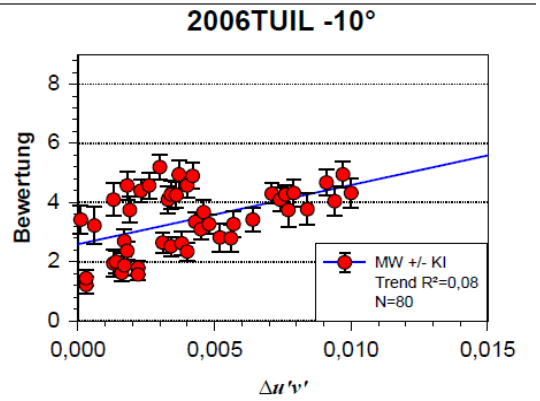












3 Result

Part 1: Analysis of Age and Color Matching Function

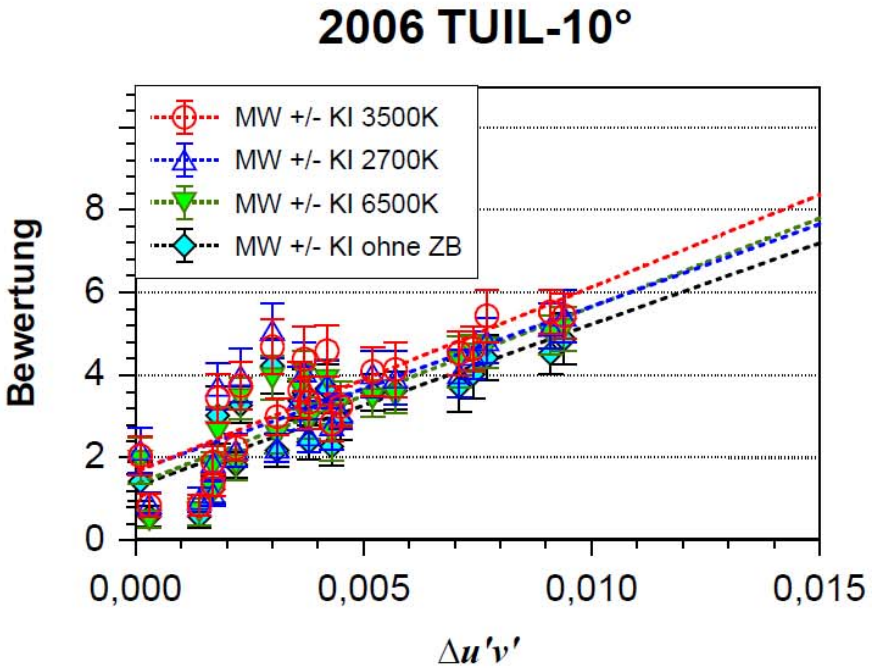
Comparisment of Coefficient of Determination (R^2)

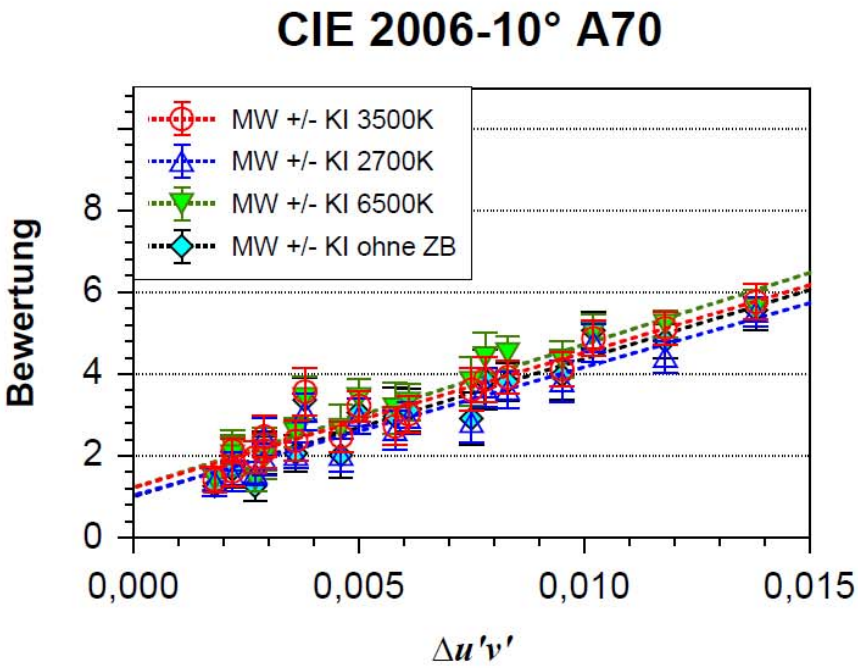
CMF	Young subjects (<35 years, N=41)	Older subjects (>60 years, N=39)	All subjects N=80
CIE 1931	0,00	0,46	0,13
CIE 2006-2°	0,04	0,39	0,16
2006 TUIL-2°	0,34	0,19	0,26
CIE 1964	0,12	0,25	0,18
CIE 2006-10°	0,21	0,17	0,19
2006-TUIL-10°	0,42	0,02	0,08
CIE 2006-10° A70	0,03	0,50	0,18
2006 TUIL-10° A70	0,00	0,41	0,11

R^2	bis 0,05	bis 0,2	bis 0,4	bis 0,8	> 0,8
Interpretation	no correlation	low correlation	medium correlation	high correlation	very high correlation

3 Result

Part 2: Analysis of the Effect of the Sorrounding Color





3 Result

Summary

- Perception of luminous color differences is age-dependent
- This effect can be described by age-dependet CMFs
- For this study the age-dependent version of CMF 2006-TUIL-10º showed the best correlation
- Use of current standard CIE1931 is not sufficient
- The surrounding color has no siginificant effect on the rating of luminous color differences

Thank you!