

Unique hue assessment on displays

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What is Unique Hue



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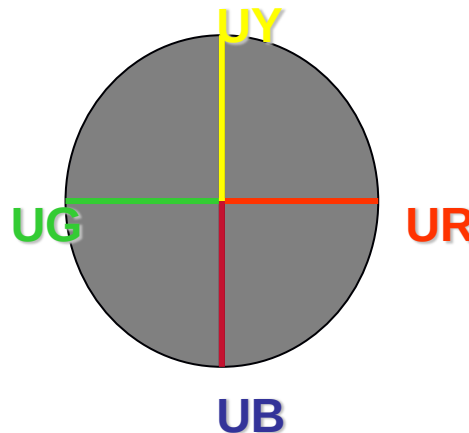
Unique Hues were originally defined by Hering as

Unique Red: Neither Yellowish nor Blueish

Unique Green: Neither Yellowish nor Blueish

Unique Yellow: Neither Reddish nor Greenish

Unique Blue: Neither Reddish nor Greenish



Unique hue is only standard in human colour perception

(We perceive more or less same unique hue)

- Why and how we perceive unique hue (Colour vision)
- How to use unique hue data to develop Uniform Colour Space and Colour appearance model (Colour Science)
- Display visual colour characterisation (display application)



Evaluation of Unique Hue Predictions in CIECAM02 by using Unique Hue Data

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Unique Hue Selection Task

Observer was asked to select a patch on the CRT that contains neither yellowish nor blueish (to obtain unique red and green). Unique yellow (blue) was obtained by asking observers to select a patch that contains neither reddish nor greenish.

Subjects

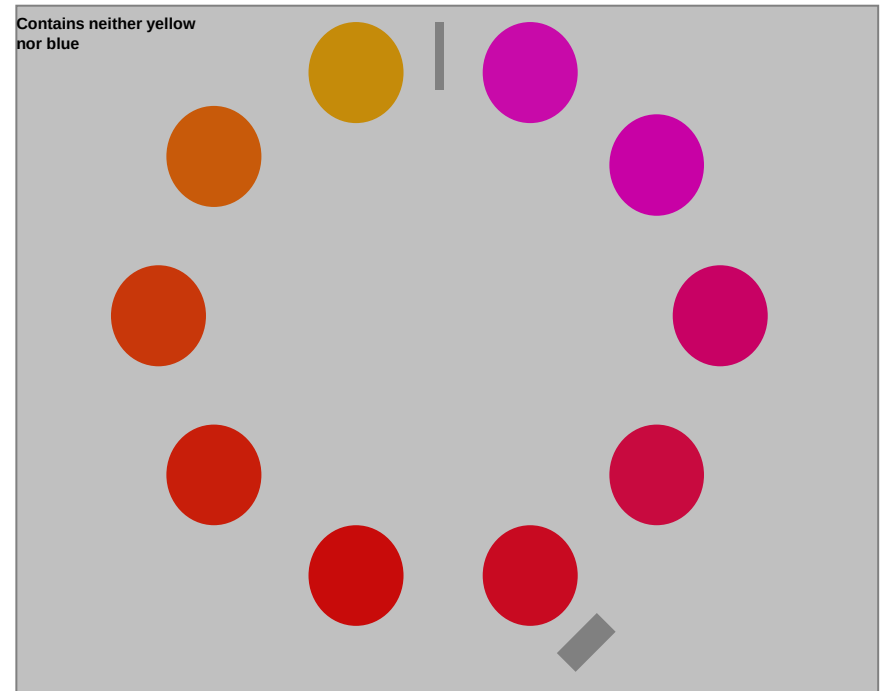
185 naïve observers with
normal colour vision
(Cambridge Trivector Test)

Repetition

Three times

Viewing Condition

Dark Room, D65, CWF



9 chroma-lightness level for each unique hue were assessed

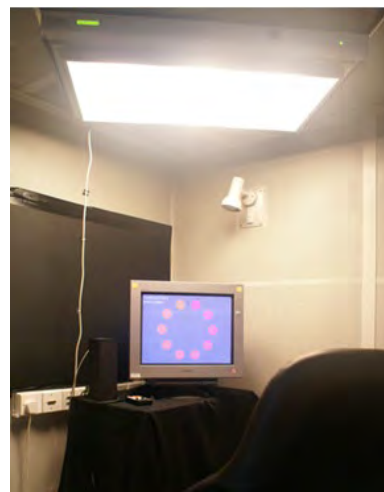


EXPERIMENT

GTI ColorMatcher GLE M5/25



CRT under D65



CRT under CWF

Room Lighting	<i>Lum</i>	<i>x</i>	<i>y</i>	<i>CCT</i>
D65	41.3	0.3229	0.3453	5917
CWF	136.8	0.3890	0.3887	3866

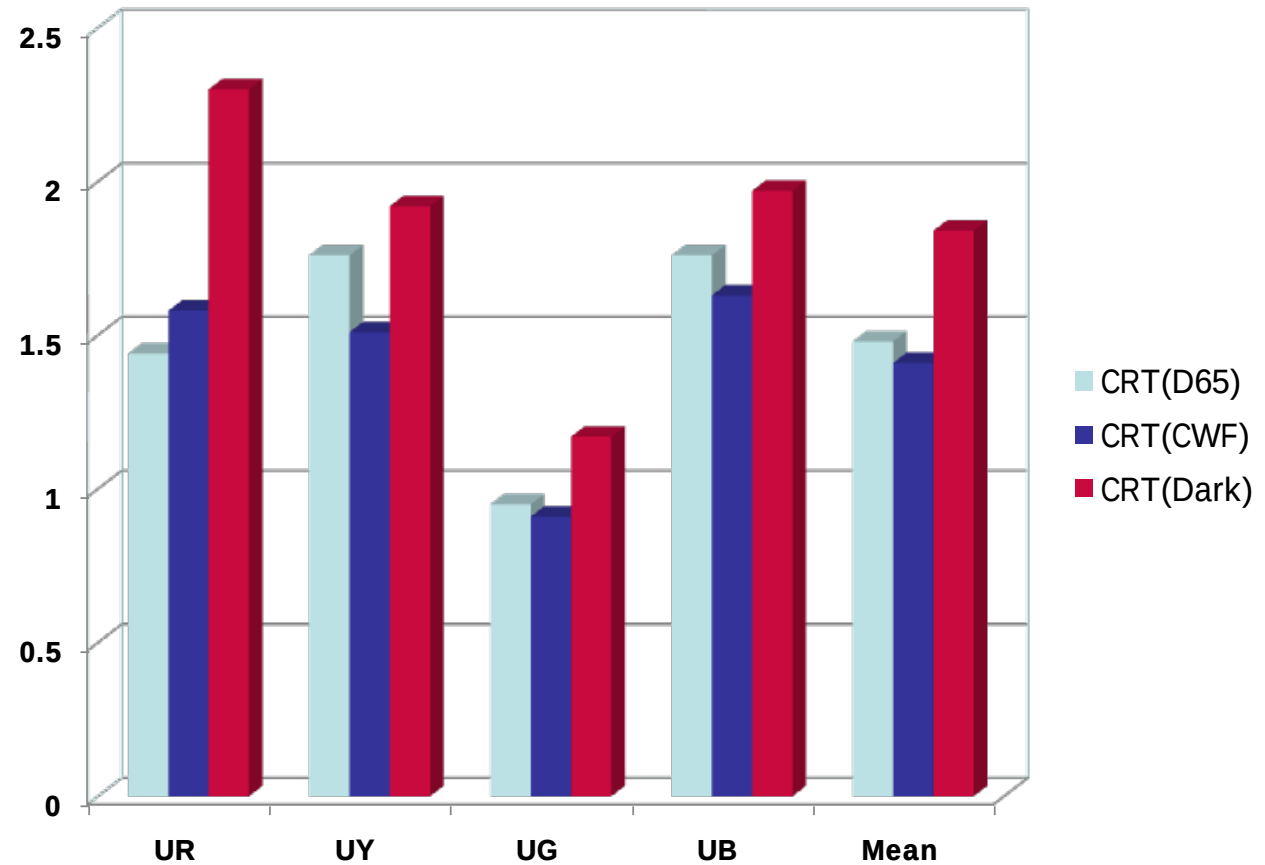


Unique Hue Data

- ☐ Each unique hue stimulus was measured with a PR-650 tele-spectroradiometer to obtain the CIE XYZ tristimulus values
- ☐ Unique Hue stimuli assessed by 185 subjects in 3 repetitions were averaged
- ☐ Three groups of Unique Hue Data (9 x 4 UHs)
 - Dark Room
 - under D65 room lighting
 - under CWF room lighting

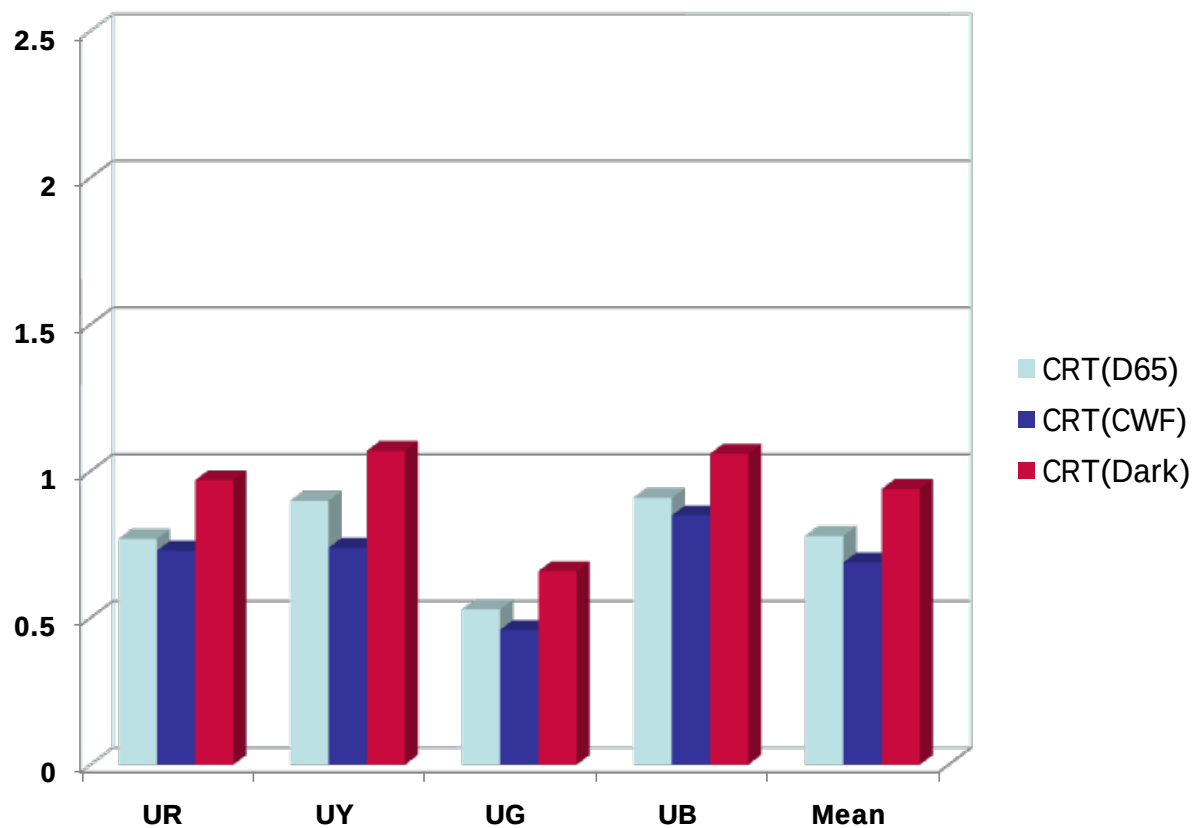


Inter-Observer Variability (ΔE_{00})



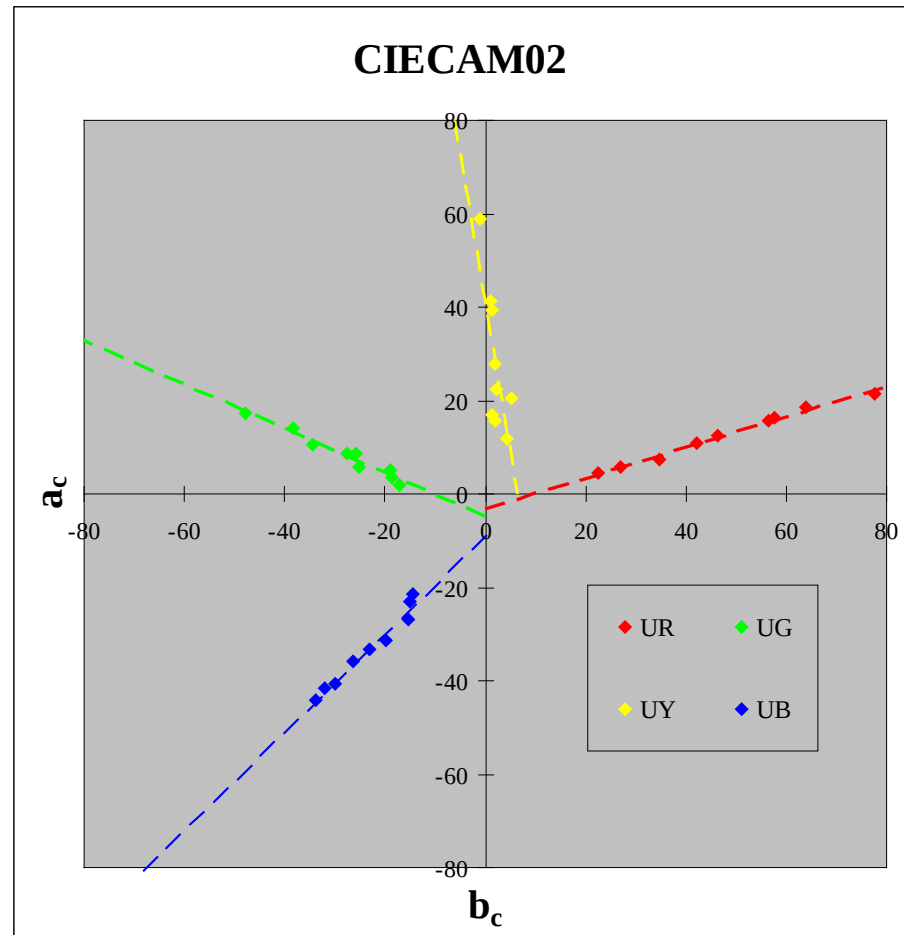


Intra-Observer Variability (ΔE_{00})





UNIQUE HUES in CIECAM02



Unique hue lines in the CIECAM02 chromatic diagram

Study 2 Unique assessment on wide colour gamut projector



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Repeat previous experiment on a wide colour gamut laser projector

	Red		Green		Yellow		Blue	
	L	C	L	C	L	C	L	C
1	40	50	30	20	50	20	30	15
2	40	78	30	45	50	40	30	30
3	40	95	30	73	50	60	30	40
4	60	60	55	40	70	30	45	20
5	60	85	55	80	70	60	45	42
6	60	110	55	110	70	80	45	53
7	75	20	75	50	90	30	60	30
8	75	45	75	100	90	50	60	53
9	75	65	75	145	90	90	60	65

9 lightness-chroma level were selected for each unique hue in CIELAB

1. Chromatic adaptation
2. Unique hue selection task
3. 18 observers, 2 repetition
4. Measurement of observer selection using TSR.



MCDM (CIEDE2000) was used to quantify intra- and inter-observer variability

	UR	UY	UG	UB	Mean
Inter	1.73	1.76	1.74	1.53	1.69
Intra	0.77	0.64	1.03	0.74	0.79

Previous study:

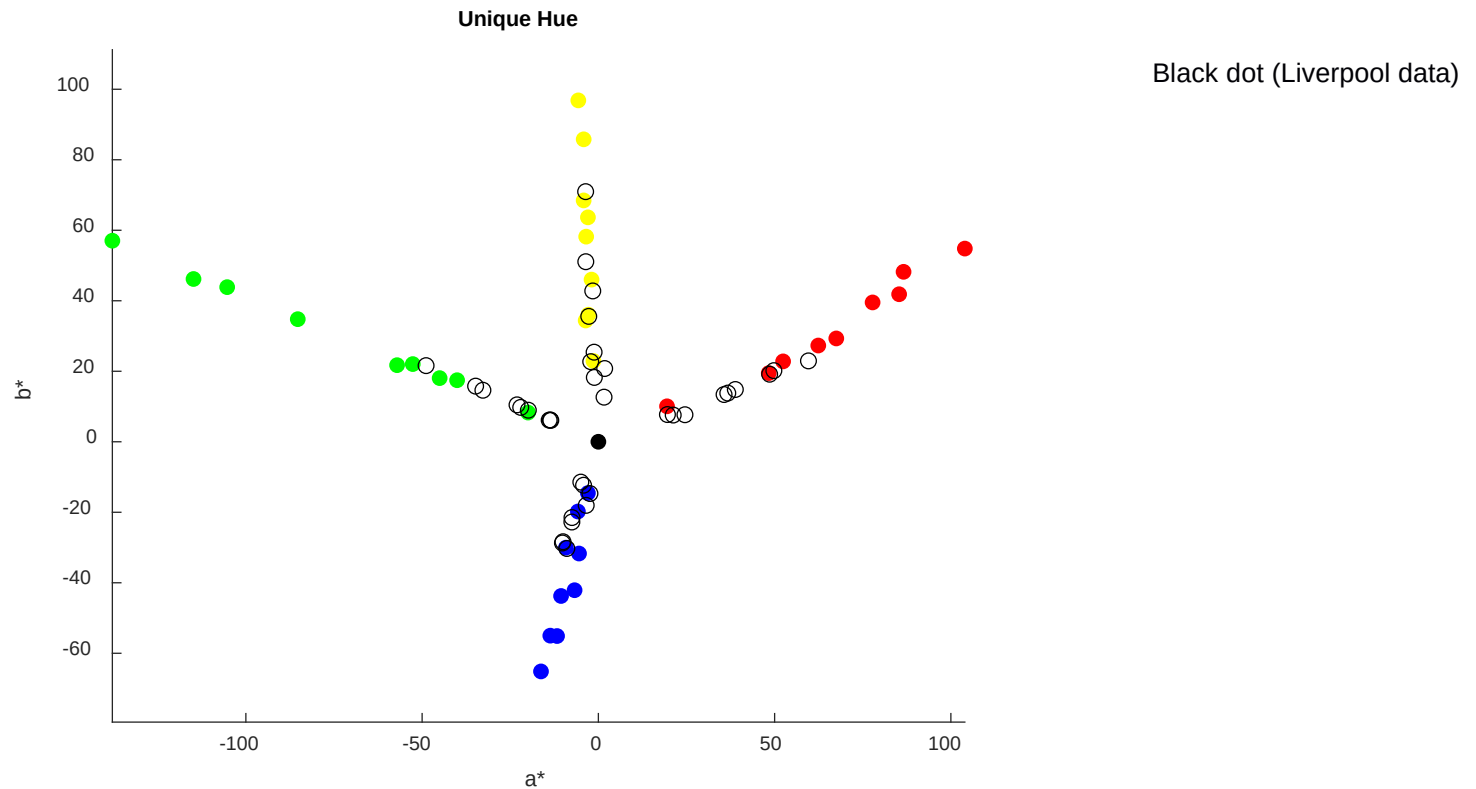
TABLE II. Observer variability.

CIEDE2000	UR	UY	UG	UB	Mean
Inter-observer	2.30	1.92	1.17	1.97	1.84
Intra-observer	0.97	1.07	0.66	1.06	0.94

Unique hue distribution in CIELAB



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Average hue angles of unique hue

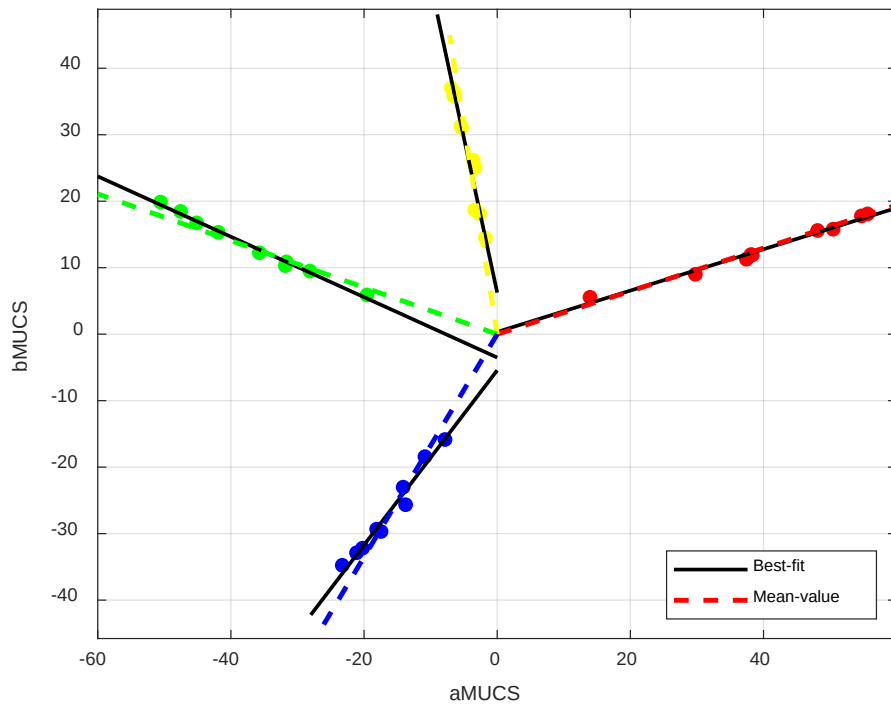
Hue angle	Red	Green	Yellow	Blue
Leeds	25.23	157.67	93.34	257.18
Liverpool	20.58	155.87	91.45	252.74

Unique hue loci in different colour space

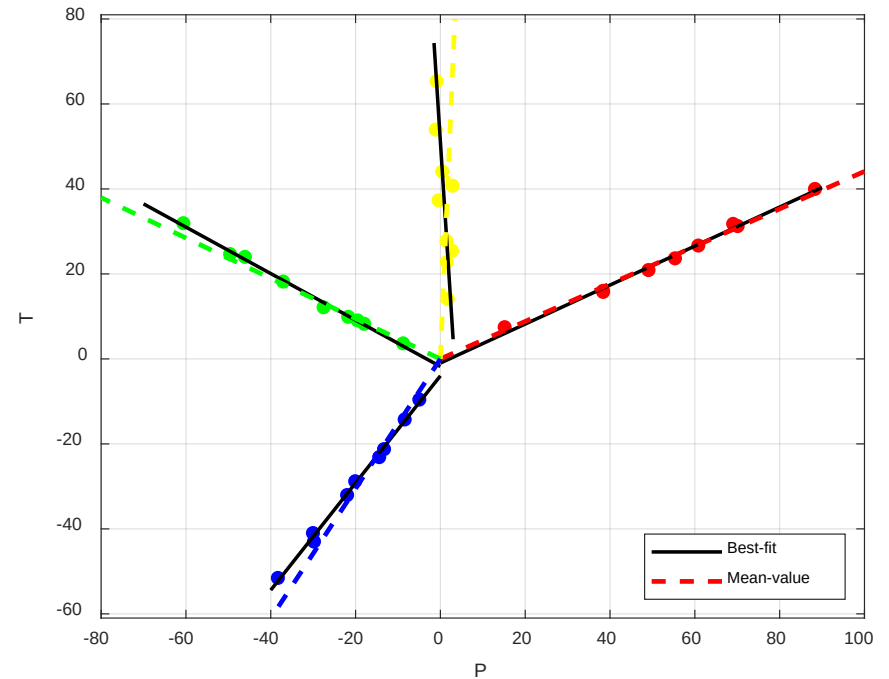


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CAM16-UCS



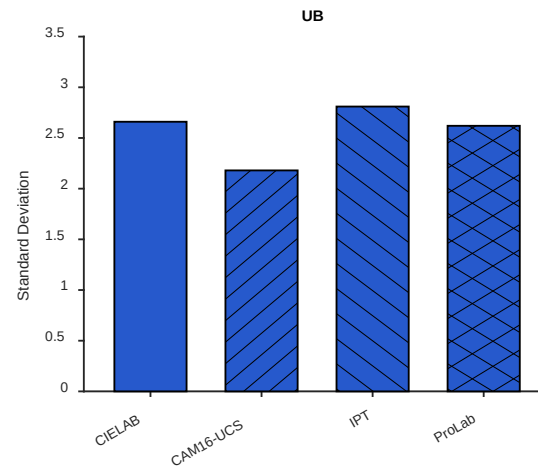
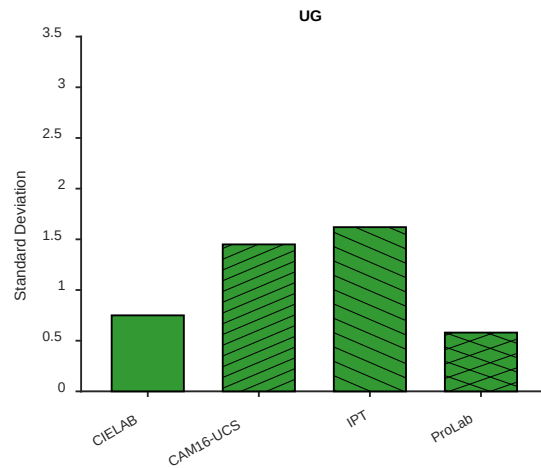
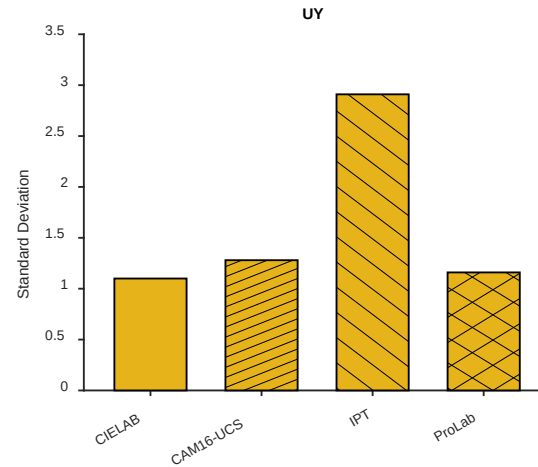
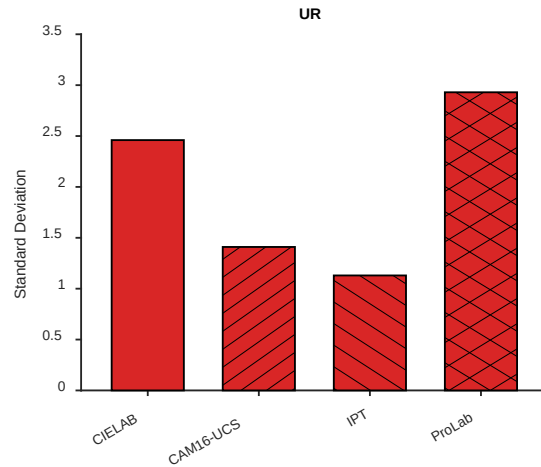
IPT



Standard deviation of unique hue angle



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CAM16 UCS is outperformed

Study 3: Unique Hue Perception in Observers with Long-Term Exposure to Low-Illuminance Environments

Qinxin He · University of Leeds

Research Aim

To examine whether unique hue locations differ between general observers and observers with long-term underground work experience.

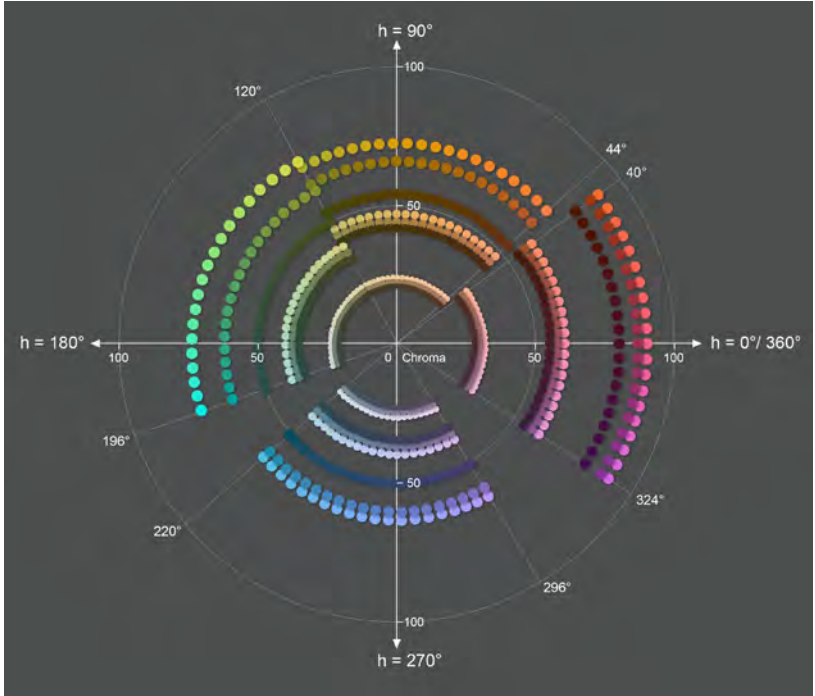
Experimental Design

➤ Participants

	Sample Size	Average Age	Age Range	Sex	Mean Years of Underground Work
General observers	28	32	20–45	16 Female 12 Male	—
Miner observers	33	36	22–56	12 Female 21 Male	12 years

➤ Test Stimuli

4 unique hues × 9 J-C combinations × 20 hue steps = 720 stimuli



The 720 colour stimuli used for unique-hue assessment in CIECAM16



Experimental apparatus

- Display: MacBook Pro (2019), colour-calibrated
- Calibration instrument: Konica Minolta CS-2000



Viewing conditions (CIECAM16)

- Reference white: XYZ = [94.6, 100, 116.4]
- L_a : 20 cd/m² Y_β : 80
- Dim surround: F = 0.9 c = 0.59 N^c = 0.9

Key Findings: Unique Hue Locations

Unique hue locations by observer group

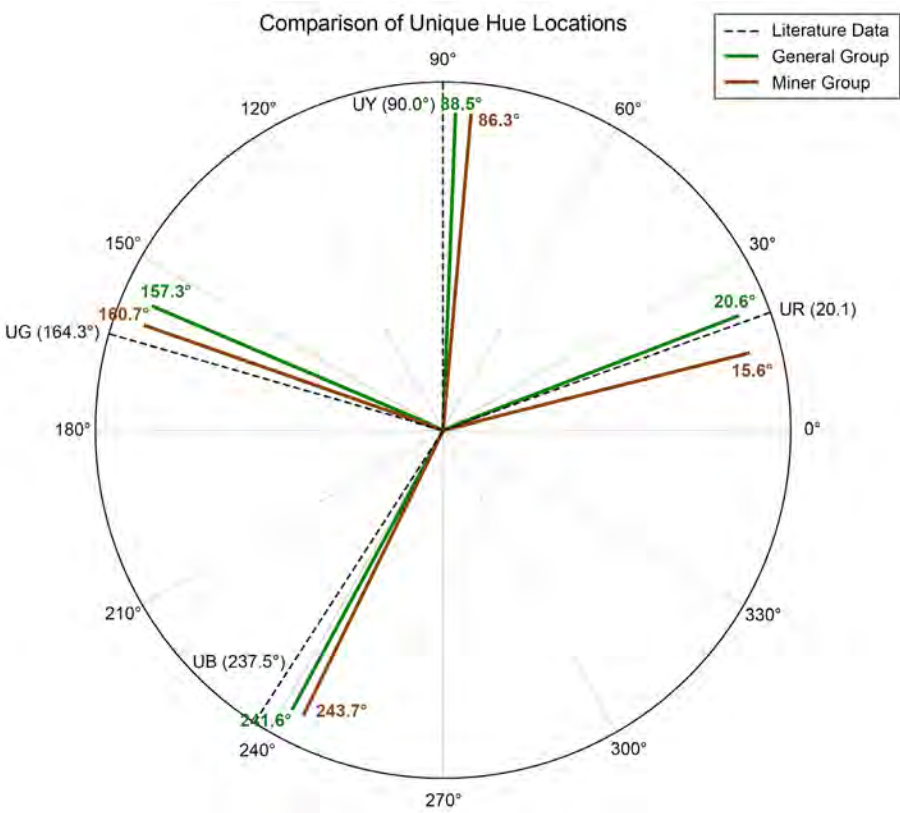
	General group	Miner group	$\Delta h_{\text{group}} = h_{\text{miner}} - h_{\text{general}}$
UR	20.6°	15.6°	-5.0°
UY	88.5°	86.3°	-2.2°
UG	157.3°	160.7°	+3.4°
UB	241.6°	243.7°	+2.1°

Difference from reference values

$\Delta h_{\text{ref}} = h_{\text{observed}} - h_{\text{reference}}$

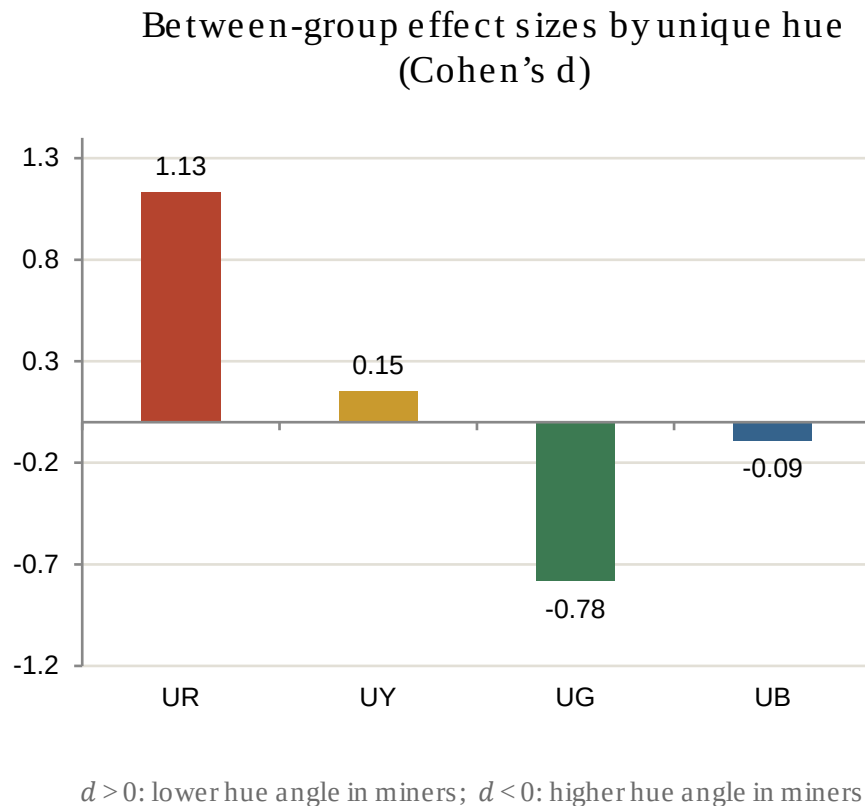
	$\Delta h_{\text{ref, general}}$	$\Delta h_{\text{ref, miner}}$
UR	+0.5°	-4.5°
UY	-1.5°	-3.7°
UG	-7.0°	-3.6°
UB	+4.1°	+6.2°

Unique hue locations differed between groups in a hue-dependent manner, with the largest difference occurring for unique red (−5.0°)



Reference: Xiao et al. (2014), Unique Hue Data for Colour Appearance Models. Part III.

Key Findings: Between-Group Differences



Group effect from mixed-design ANOVA

- UR—Significant group difference (lower in miners)
 $F(1, 59) = 19.42, p < .001$
- UG—Significant group difference (higher in miners)
 $F(1, 59) = 9.31, p = .003$
- UY—No significant group difference
 $F(1, 59) = 0.36, p = .553$
- UB—No significant group difference
 $F(1, 59) = 0.13, p = .722$

- Group differences were specific to red and green, rather than a global shift across all four hues.
- UR and UG remained significant after Bonferroni correction (adjusted $\alpha = .0125$).

Unique hue data were assessed on CRT display, wide colour gamut projector, Mini-LED (normal group vs. Miner group)

- Small observer variability
- Unique hue line do not cross origin of colour space
- Unique hue line do not averagely distribute (angle between UR and UB are much larger)

Question: Development uniform colour space

Whether unique hue line should go through origin point

Whether unique hue line should evenly distribute