Vision Experiment on Verification of Hunt Effect for Lighting

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Outline

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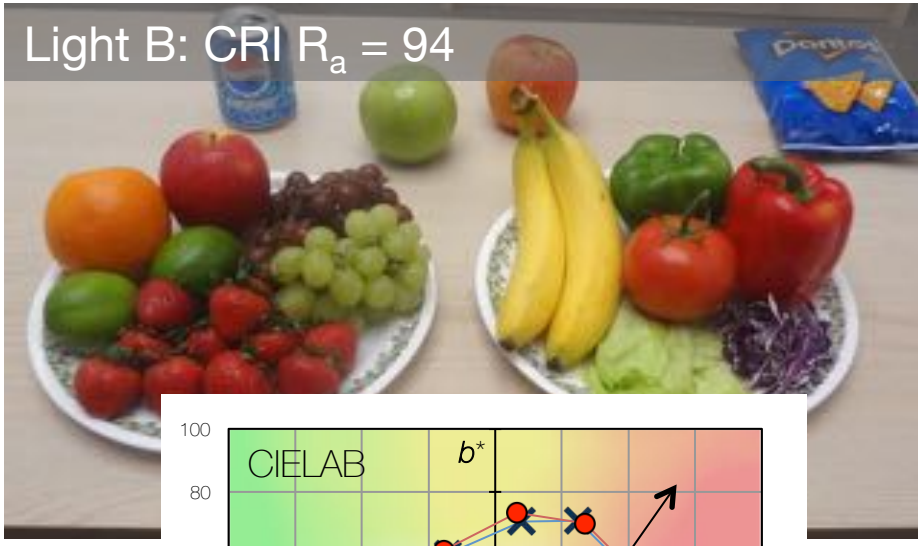
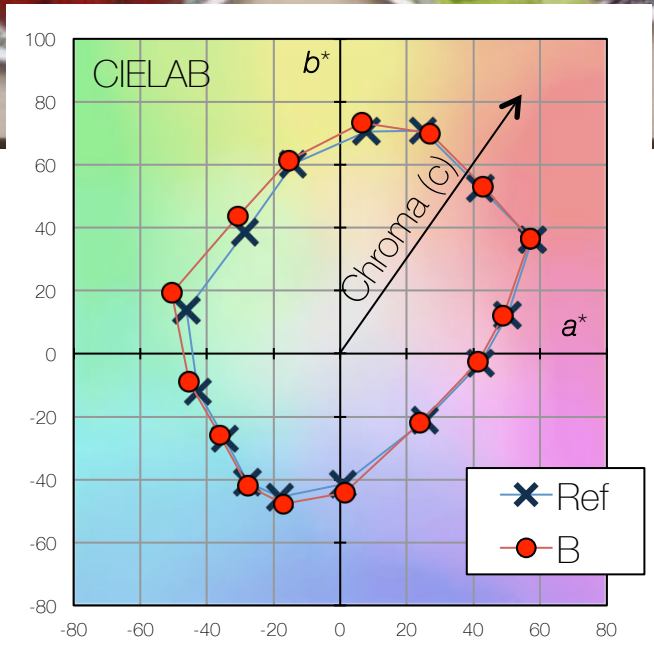
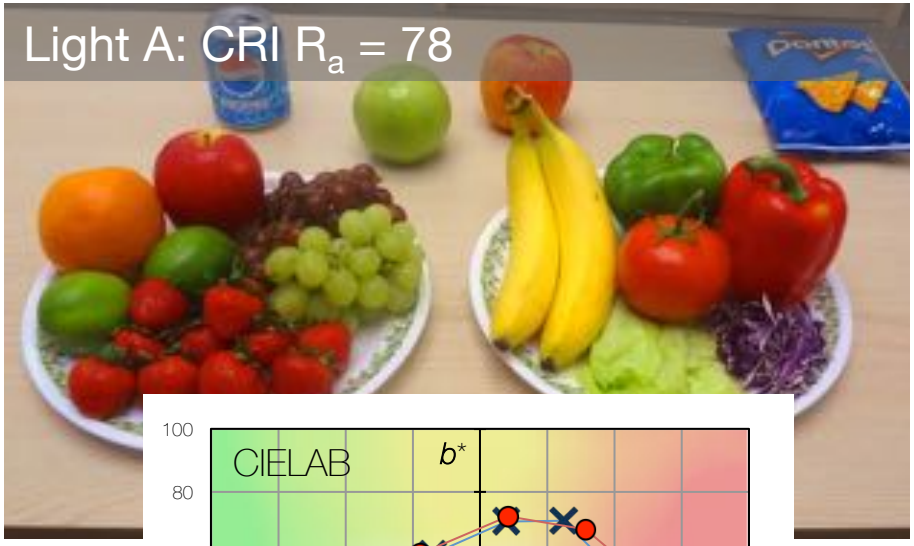
  - Demo
  - Problem of CRI
  - Hunt Effect
  - Purpose
  - Hypothesis
- Method
  - Apparatus - NIST STLF
  - Experimental conditions
  - Procedures and subjects
- Result
- Discussion
- Conclusions

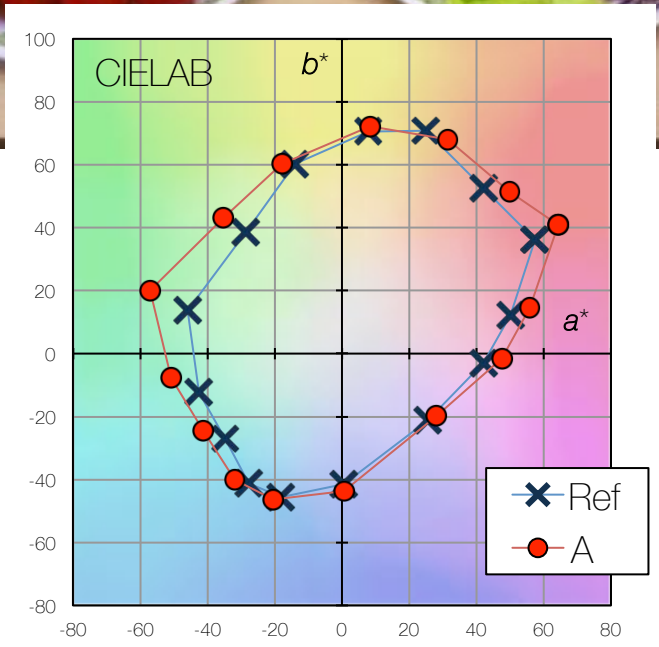
Introduction - Problem of CRI

- Color Rendering Index (CRI) often does not correlate well with perceived color rendering of illuminated scenes
- The discrepancy mainly occurs when the chroma of objects is enhanced by lighting









Introduction - Problem of CRI

Color quality

Color fidelity

CRI | CIE Rf

- CRI is a color fidelity metric, based on comparison to the reference Illuminant
- Perception is different from color fidelity

Color Perception

Preference

Naturalness

Feeling of contrast

etc.

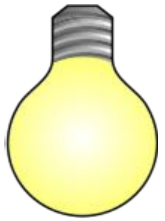
Hunt Effect

Introduction - Hunt Effect

Hunt Effect

Under low illuminance levels,
object colors are perceived less saturated

>10,000 lx

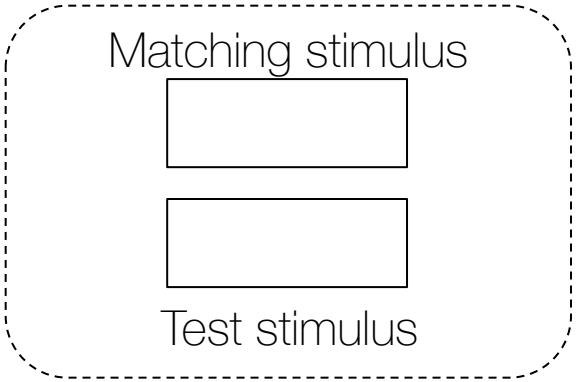


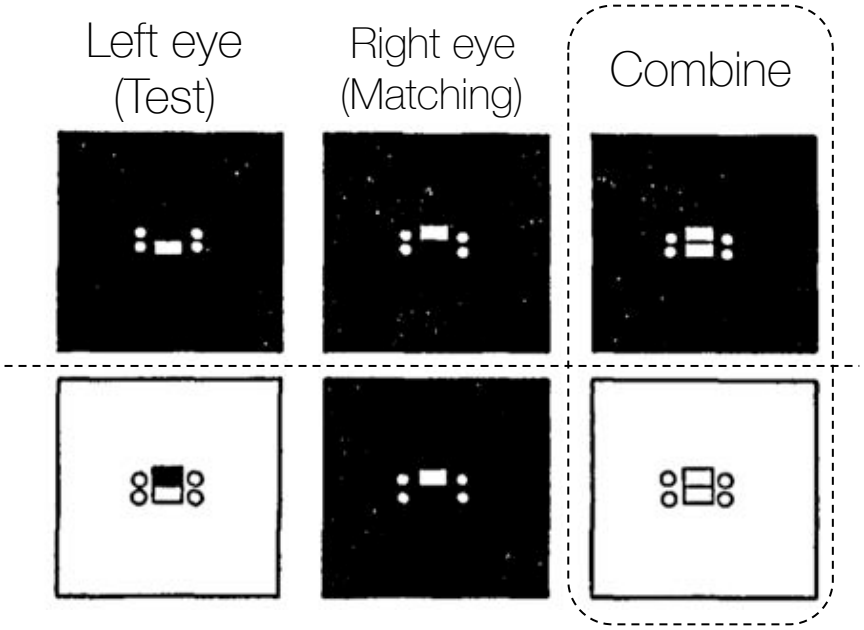
100 ~ 500 lx

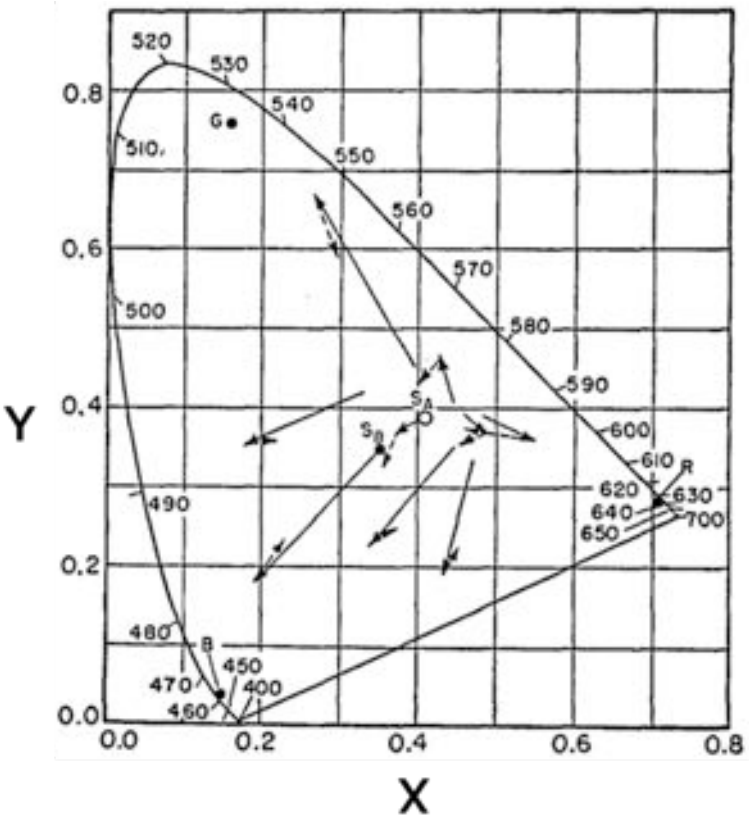
- Increased chroma → more natural (higher fidelity)
- This has not been studied at light levels for general lighting

Introduction - Hunt Effect

Hunt, R. W. G. (1950). The effects of daylight and tungsten light-adaptation on color perception. *JOSA*, 40(6), 362-371.







- Perceived chroma increased at high light levels compared to that at low light levels

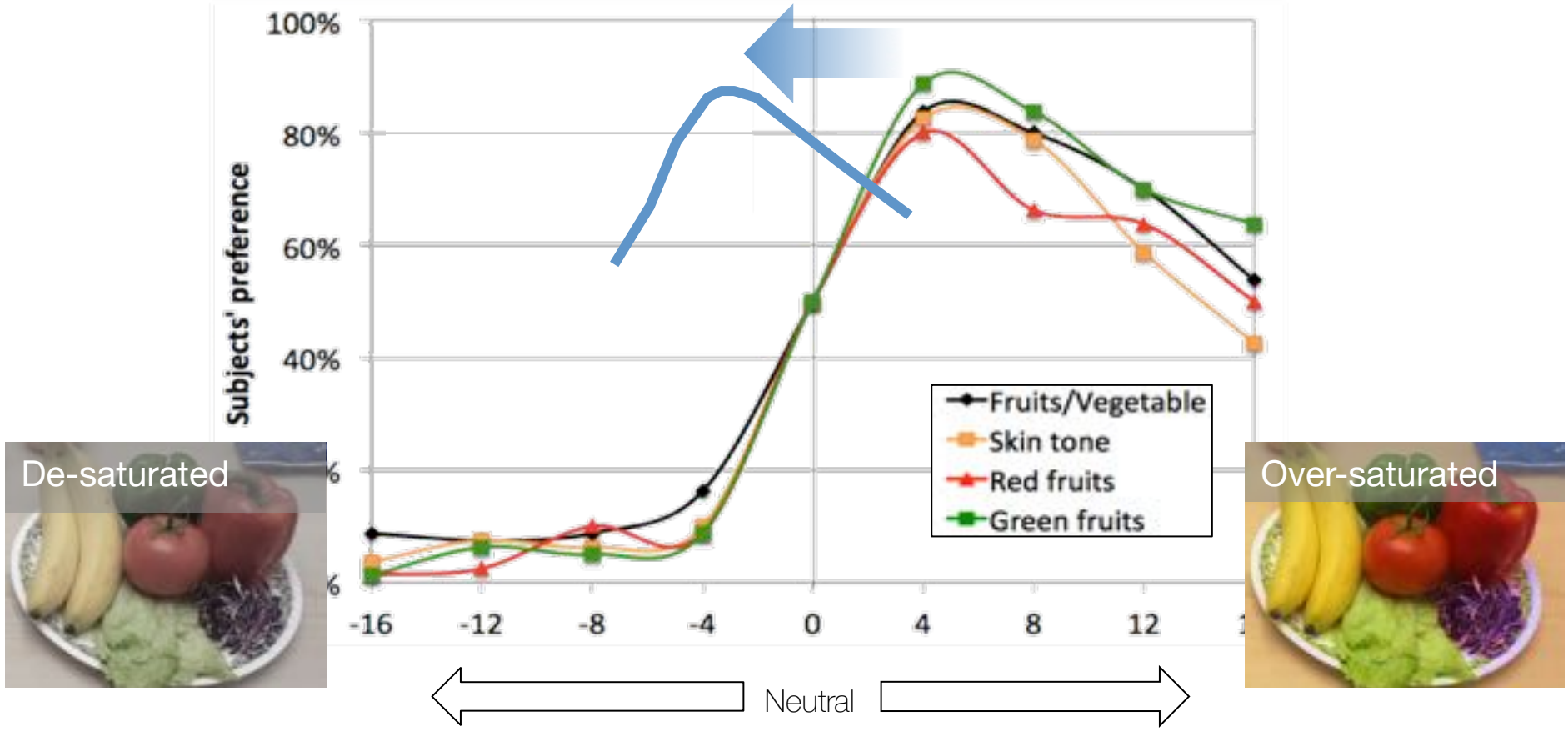
This effect has not been investigated for light level in general lighting

Introduction - Purpose

Investigating whether *Hunt Effect* is effective at normal indoor lighting

Introduction - Hypothesis

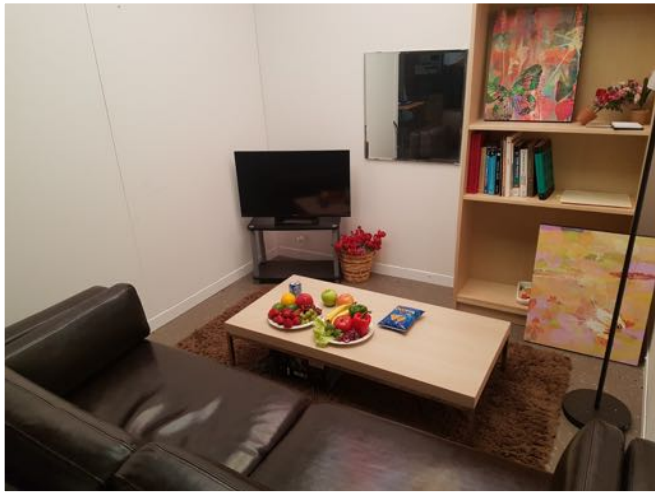
NIST 2014 experiment on chroma saturation preference

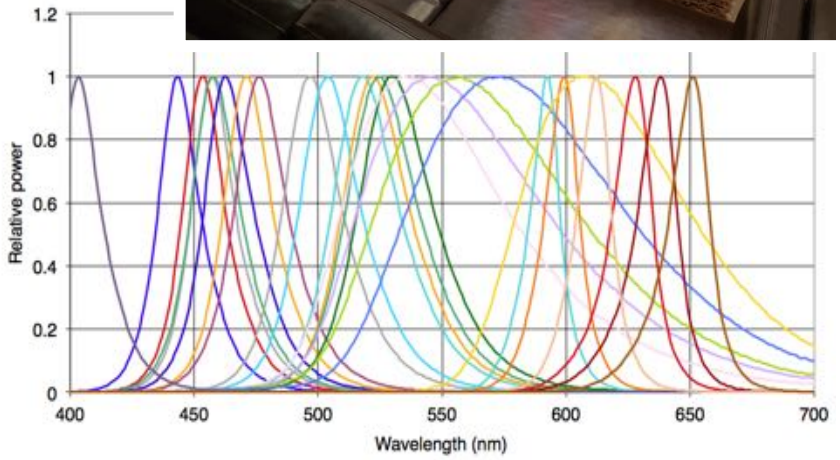


Ohno, Y., Fein, M., & Miller, C. (2015). Vision experiment on chroma saturation for color quality preference. *28th CIE Session*, 109-118.

Method - Apparatus

STLF
(Spectrally Tunable Lighting Facility)



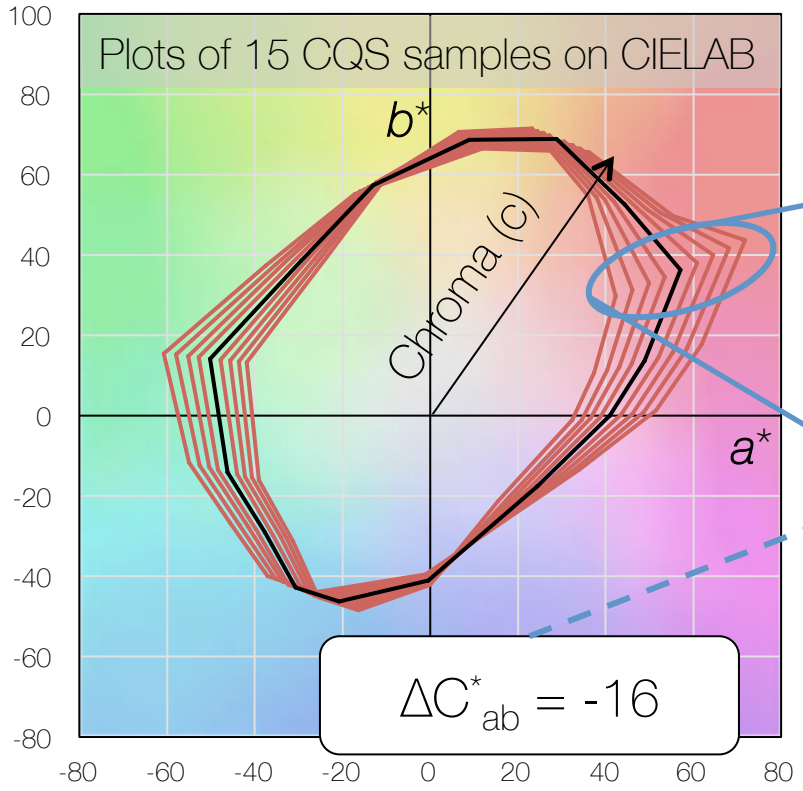


- Real-size room (2.5 m x 2.5 m cubicles)
- 25 channels of LED spectra (from 405 nm to 650 nm peak)
- STLF can control

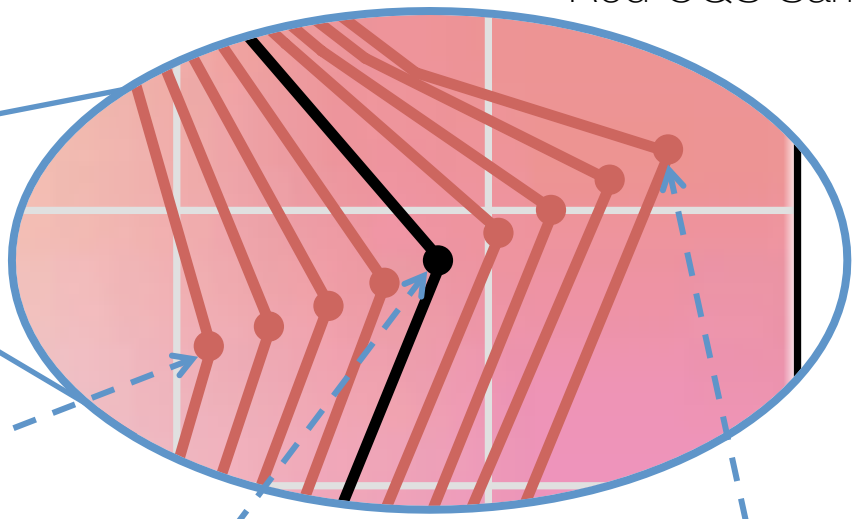
Spectral distribution | CCT | Duv | Illuminance

Method - Experimental conditions

Which light looks more natural?



Red CQS Sample

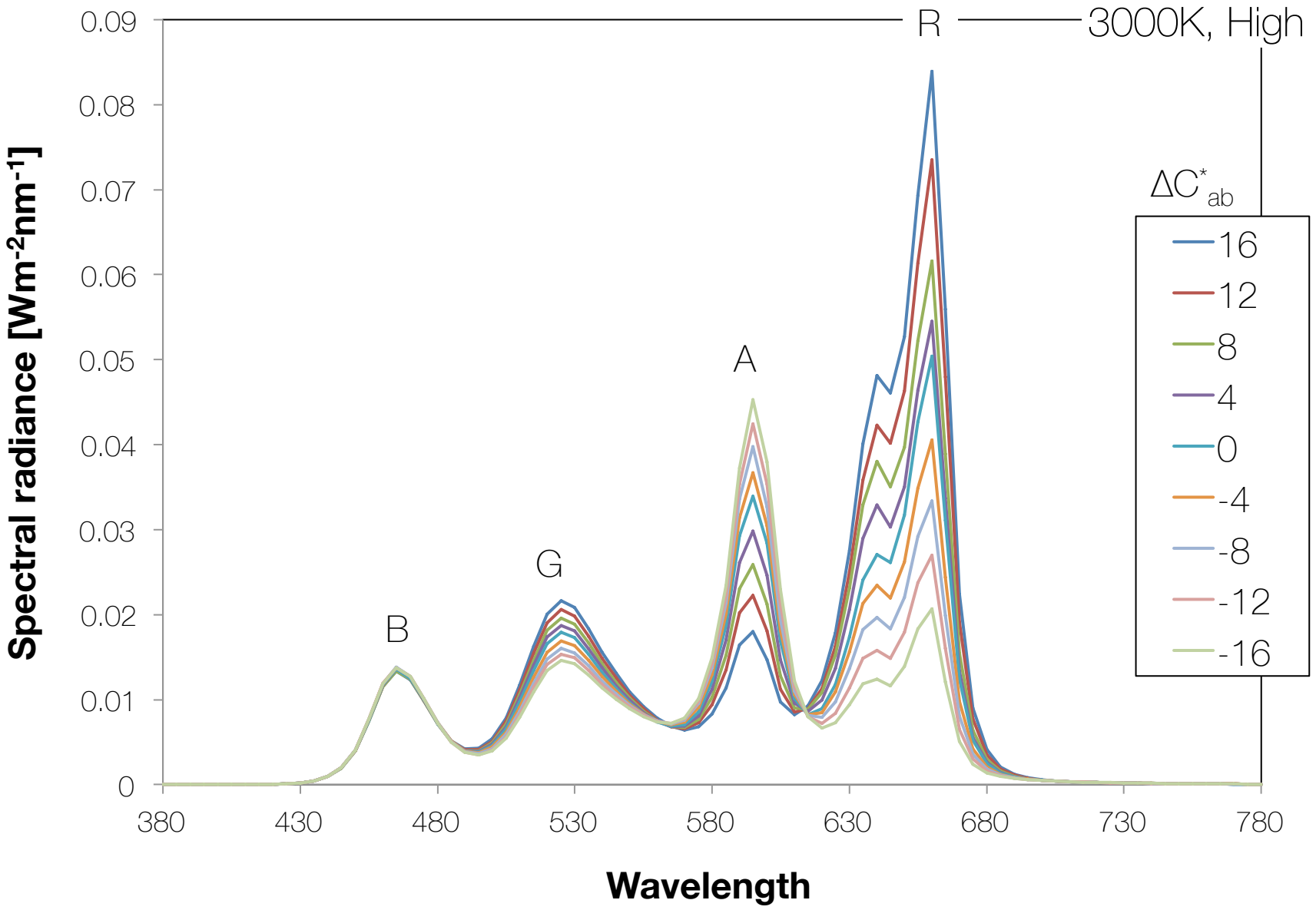


$\Delta C^*_{ab} = -16$

$\Delta C^*_{ab} = 0$

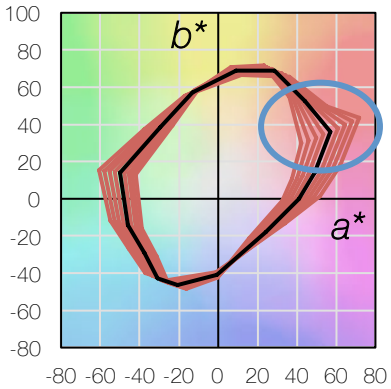
$\Delta C^*_{ab} = +16$

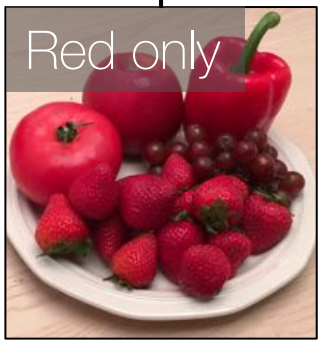
Method - Experimental conditions



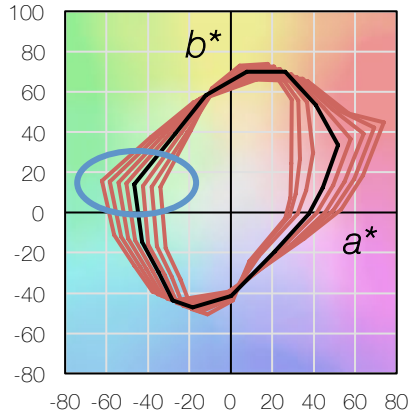
Method - Experimental conditions

- CCT: 3000 K | 5000 K
- Illuminance: 1000 lx (High) | 100 lx (Low)
- Target



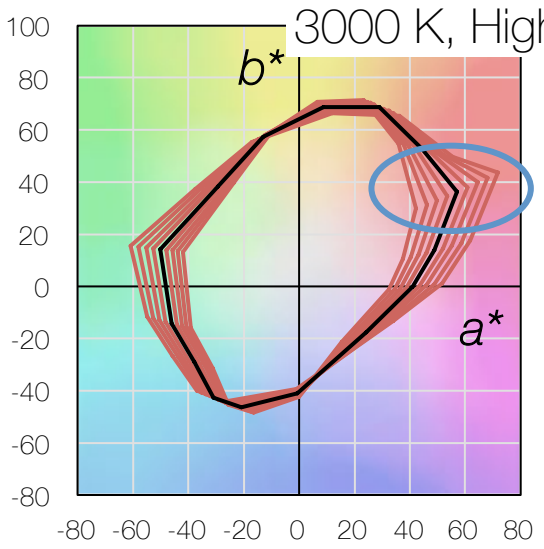


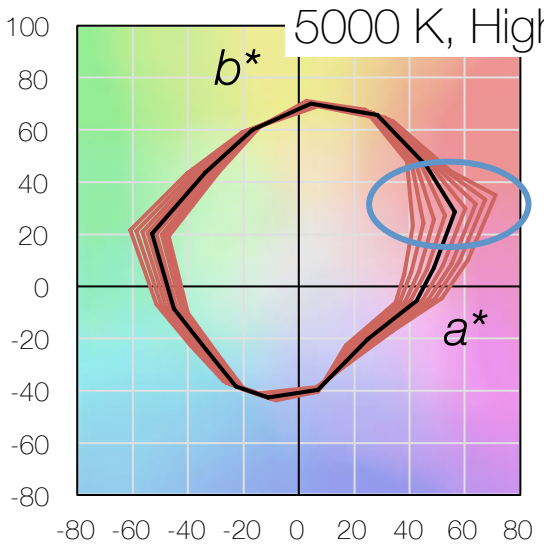
at only **3000 K** with

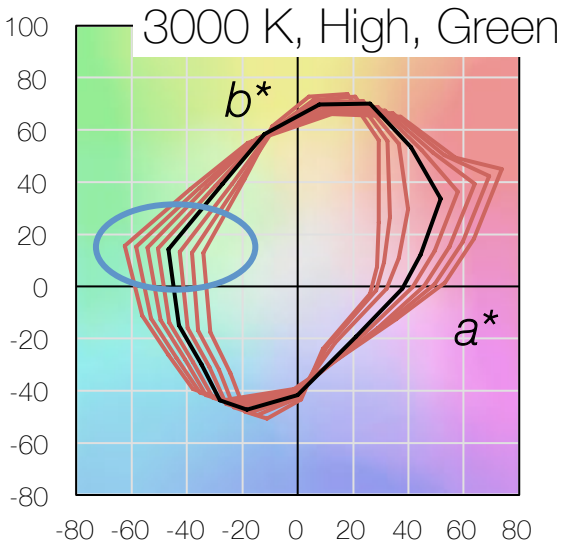


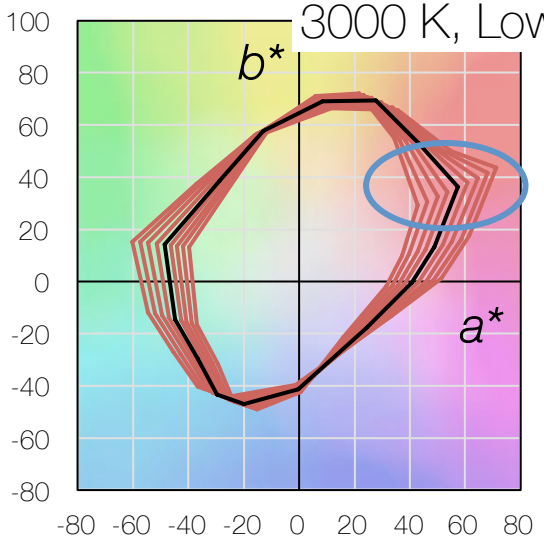
- Using the green CQS sample
- ΔC^*_{ab} in green direction
- ΔC^*_{ab} = -12 ~ +16

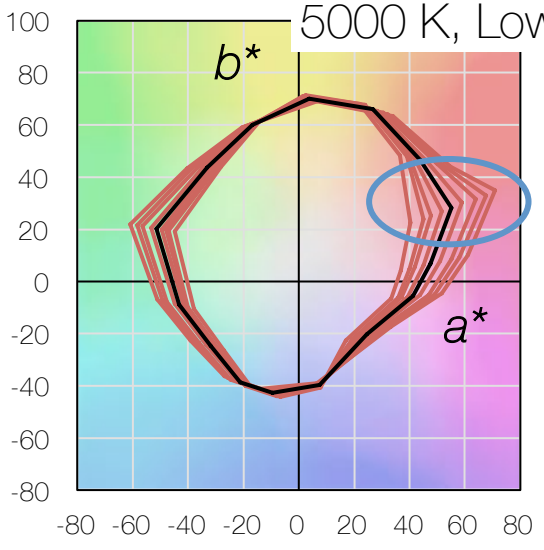
Method - Experimental conditions

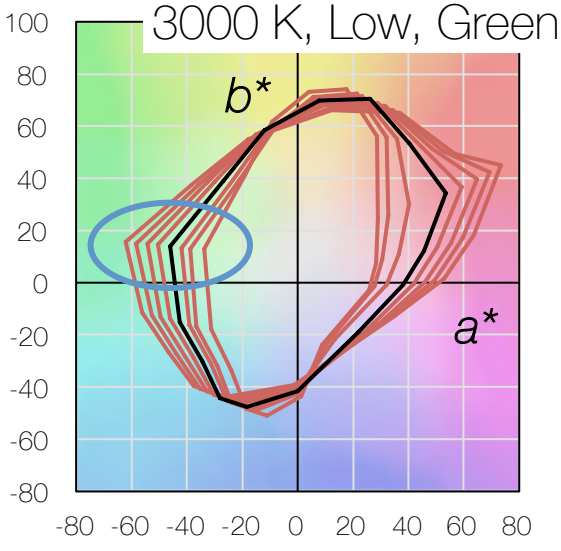






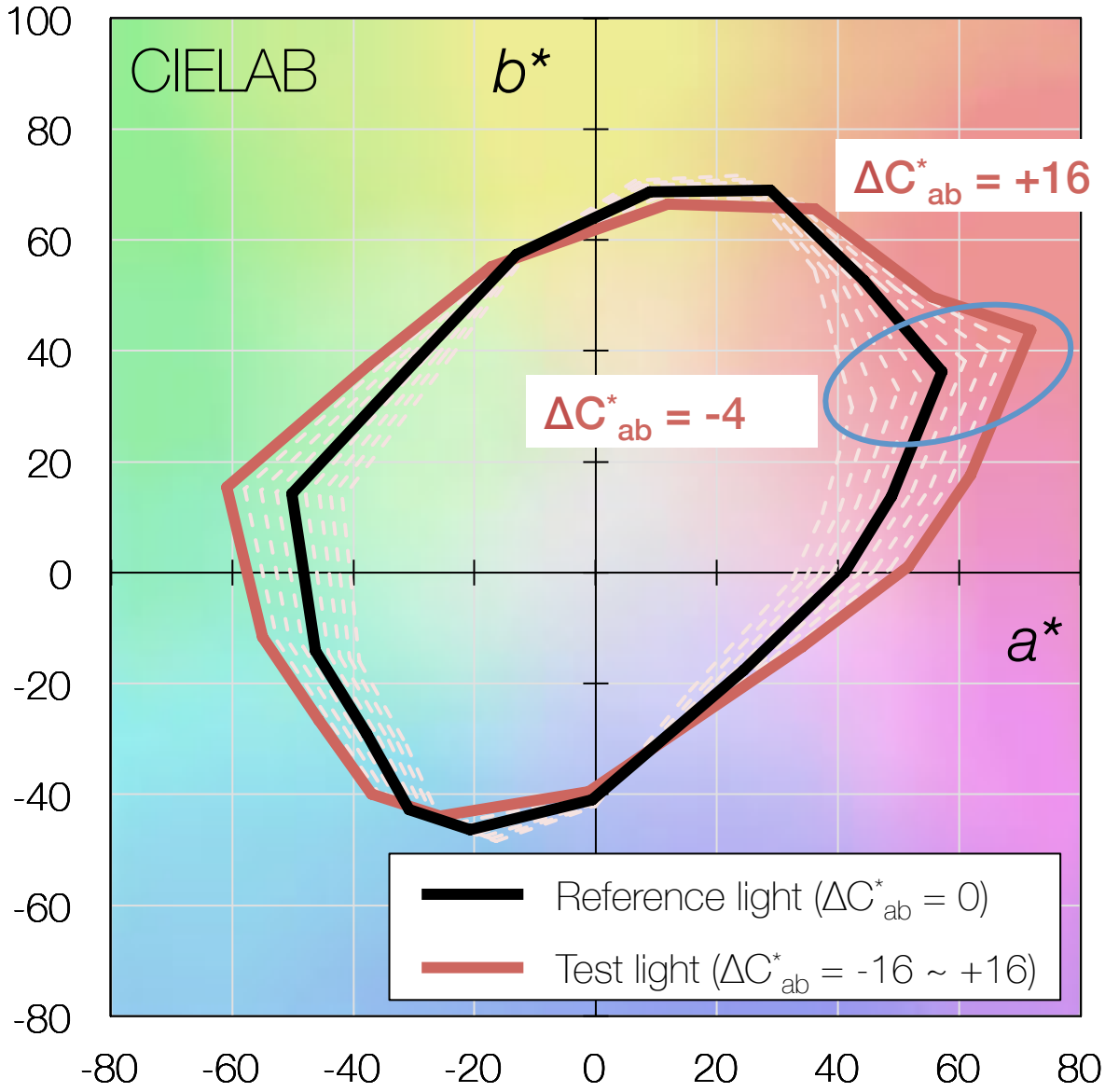






$\Delta C^*_{ab} = -12 \sim +16$

Method - Procedures and subjects



- A pair of lights was presented sequentially
- One was always reference light ($\Delta C^*_{ab} = 0$).
- Each light was called “A” and “B”
- “A” and “B” assigned randomly
- Each light presented for a few seconds
- Two lights were switched back and forth for a few times as necessary

Method - Procedures and subjects

Subjects

- Total 24 (12 males and 12 females, age 19 to 64)

Experimental Sessions

- 12 sessions (Table on the right)
- The order of sessions were changed for different subjects

Stabilization (STLF)

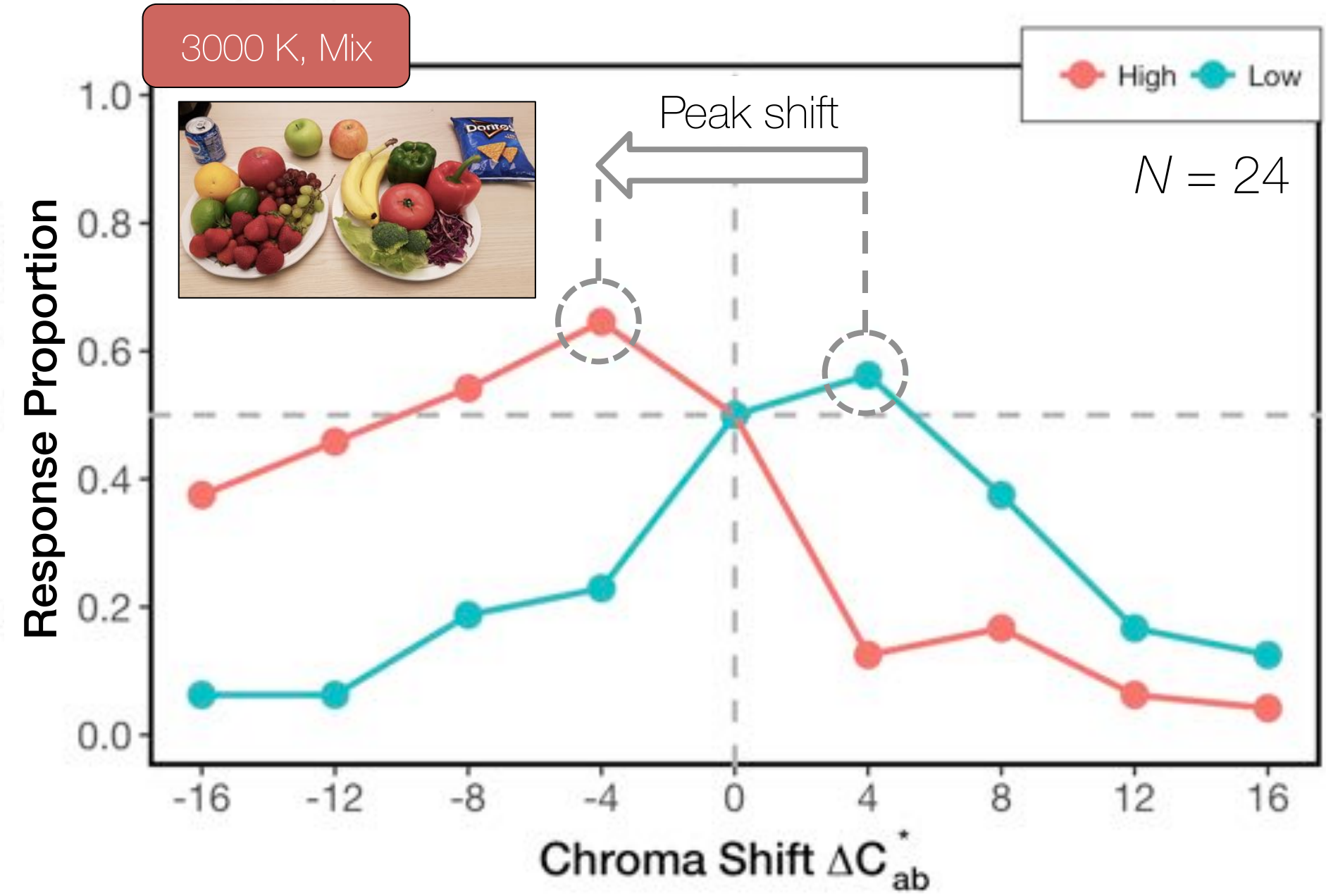
- 10 min when illuminance level changed

Adaptation (subjects)

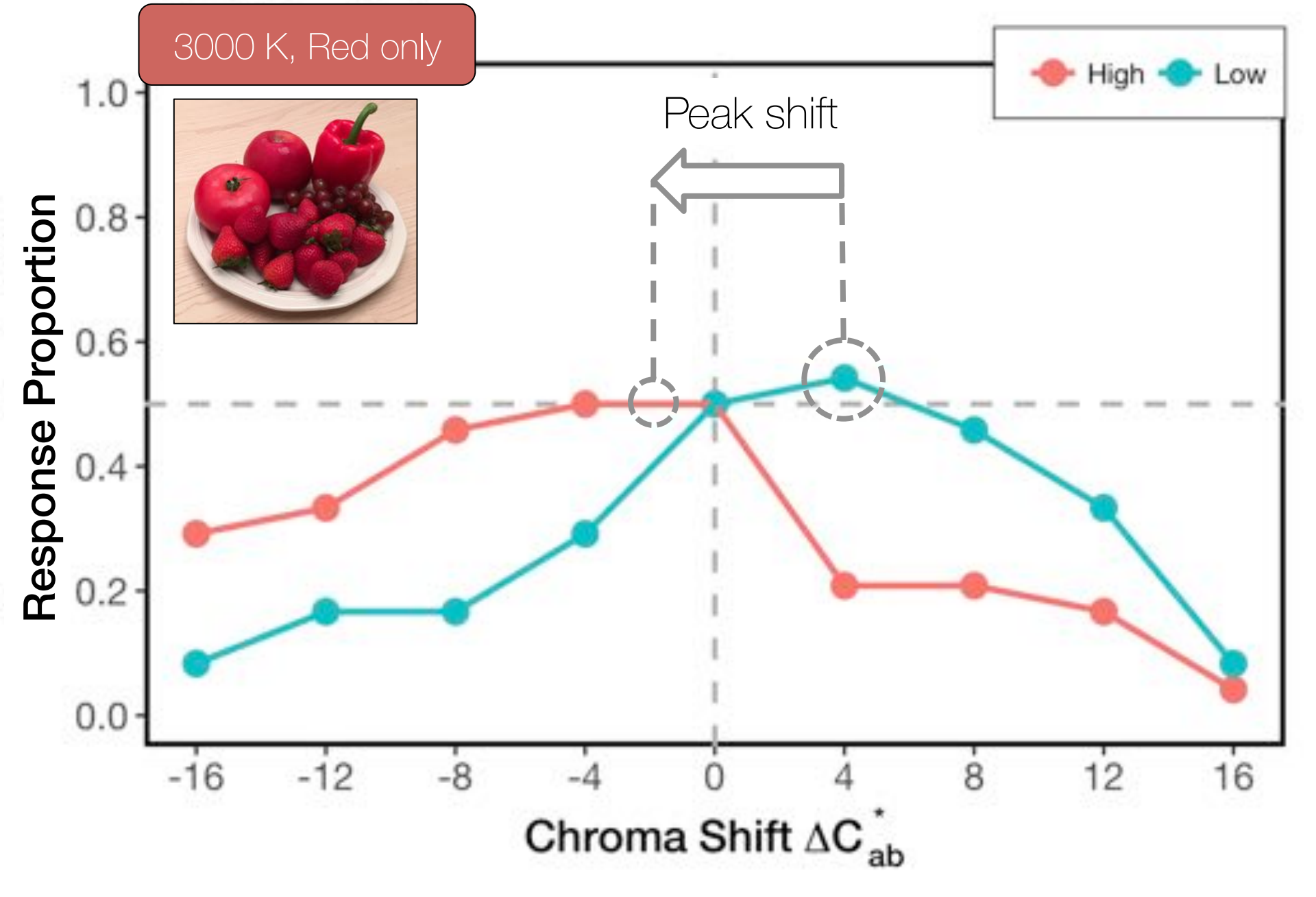
- 5 min : after illuminance was changed
- 3 min : after CCT was changed

Session	Target	CCT	Illuminance
1	Mix	3000 K	High (1000 lx)
2	Skin		
3	Red only		
4	Green only		
5	Mix	5000 K	
6	Skin		
7	Mix	3000 K	Low (100 lx)
8	Skin		
9	Red only		
10	Green only		
11	Mix	5000 K	
12	Skin		

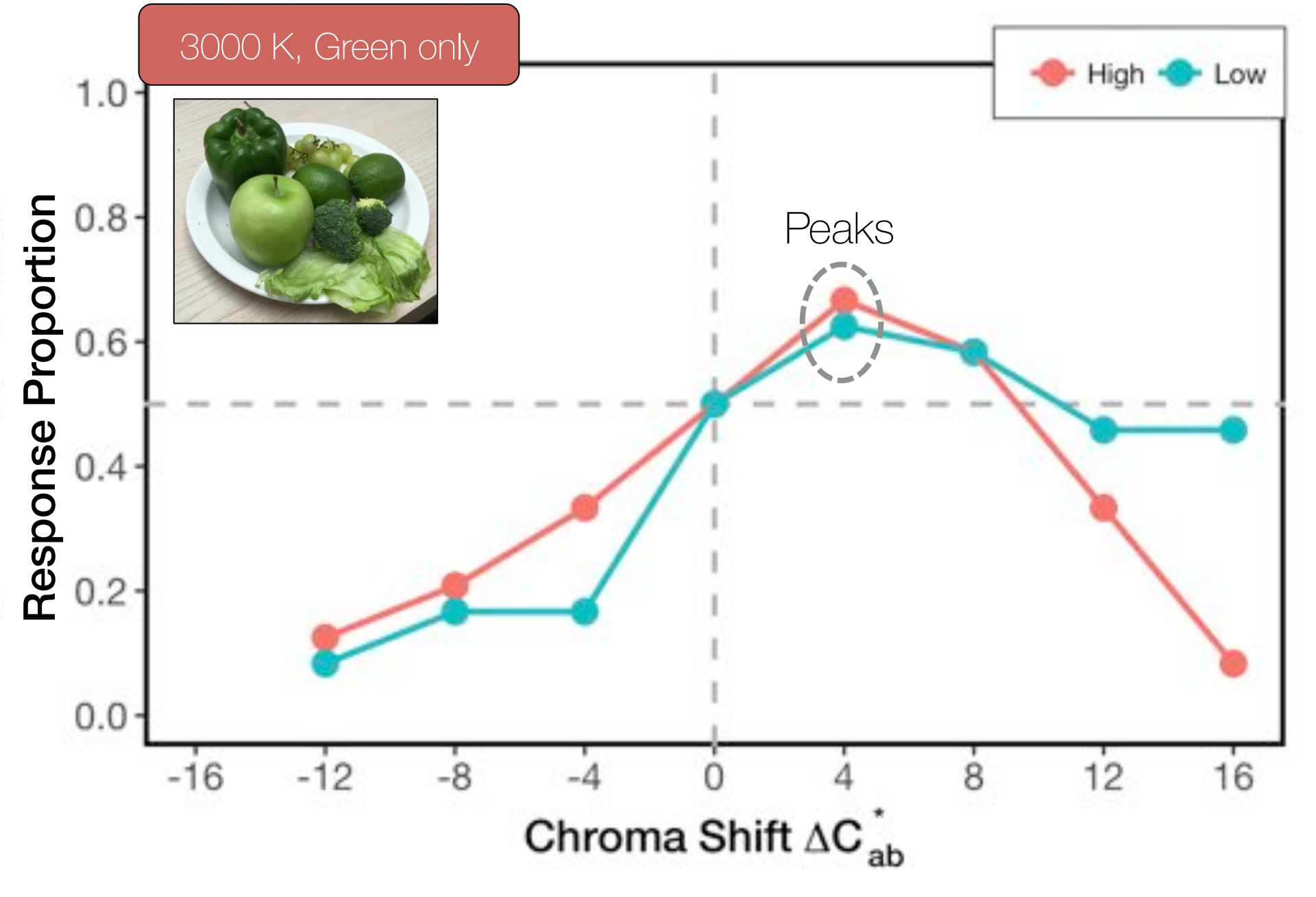
Result


3000 K, Mix
High
Low
Peak shift
N = 24
Response Proportion
1.0
0.8
0.6
0.4
0.2
0.0
-16
-12
-8
-4
0
4
8
12
16
Chroma Shift ΔC*ab

Result


3000 K, Red only
High
Low
Peak shift
Response Proportion
1.0
0.8
0.6
0.4
0.2
0.0
-16
-12
-8
-4
0
4
8
12
16
Chroma Shift ΔC*ab

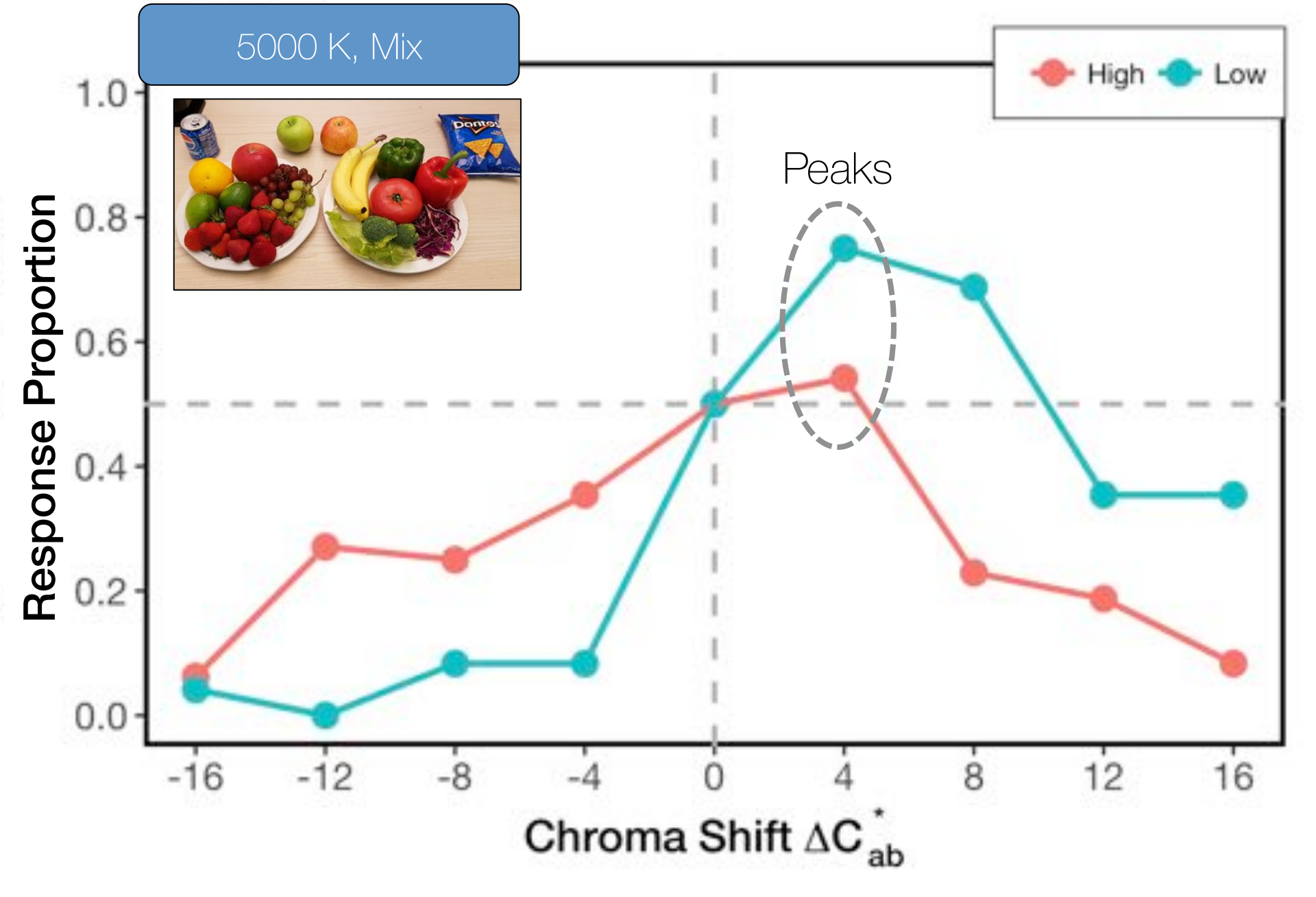
Result


3000 K, Green only
High
Low
Peaks
Response Proportion
1.0
0.8
0.6
0.4
0.2
0.0
-16
-12
-8
-4
0
4
8
12
16
Chroma Shift ΔC*ab

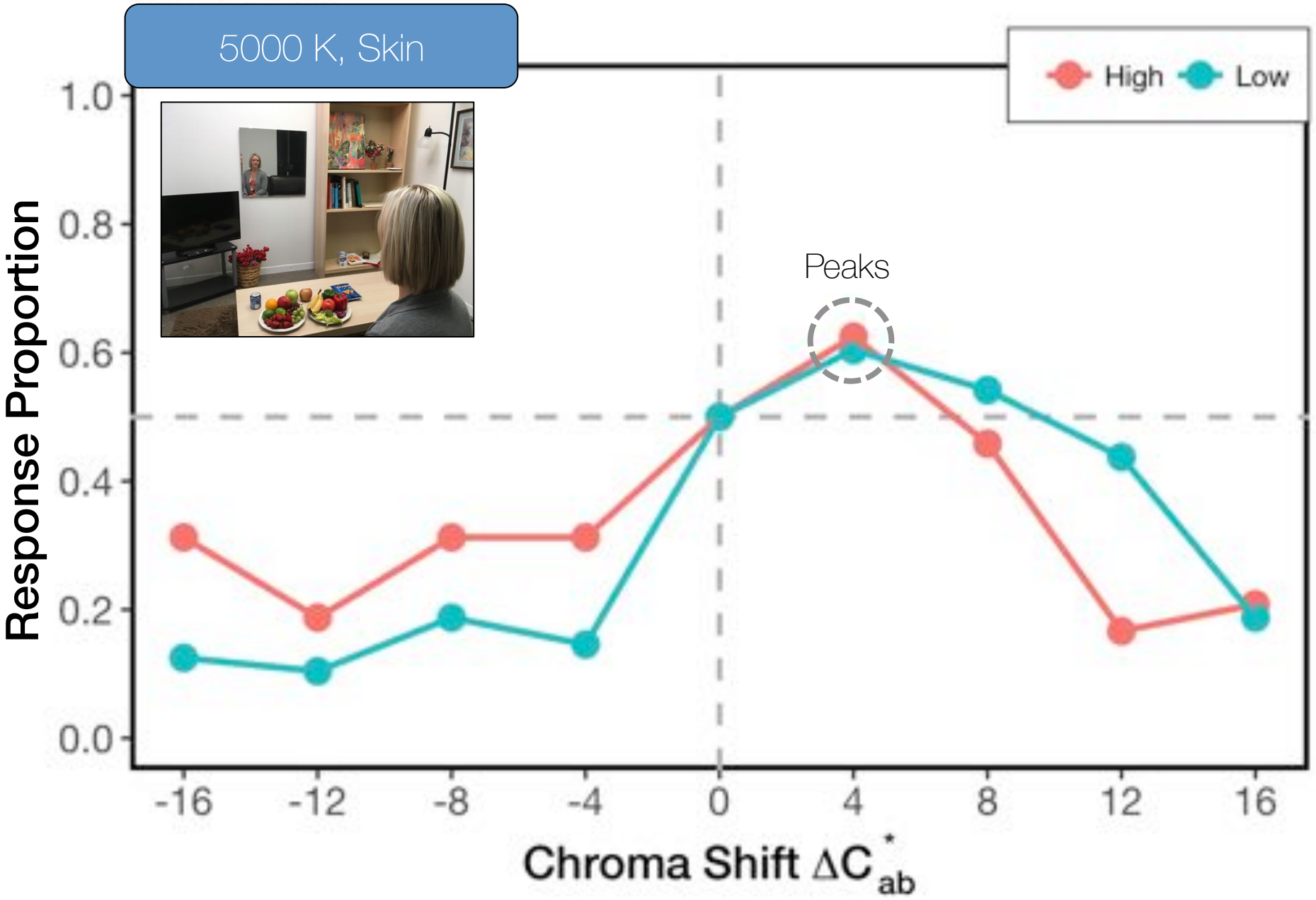
Result


3000 K, Skin
High
Low
Peaks
Response Proportion
1.0
0.8
0.6
0.4
0.2
0.0
-16
-12
-8
-4
0
4
8
12
16
Chroma Shift ΔC*ab

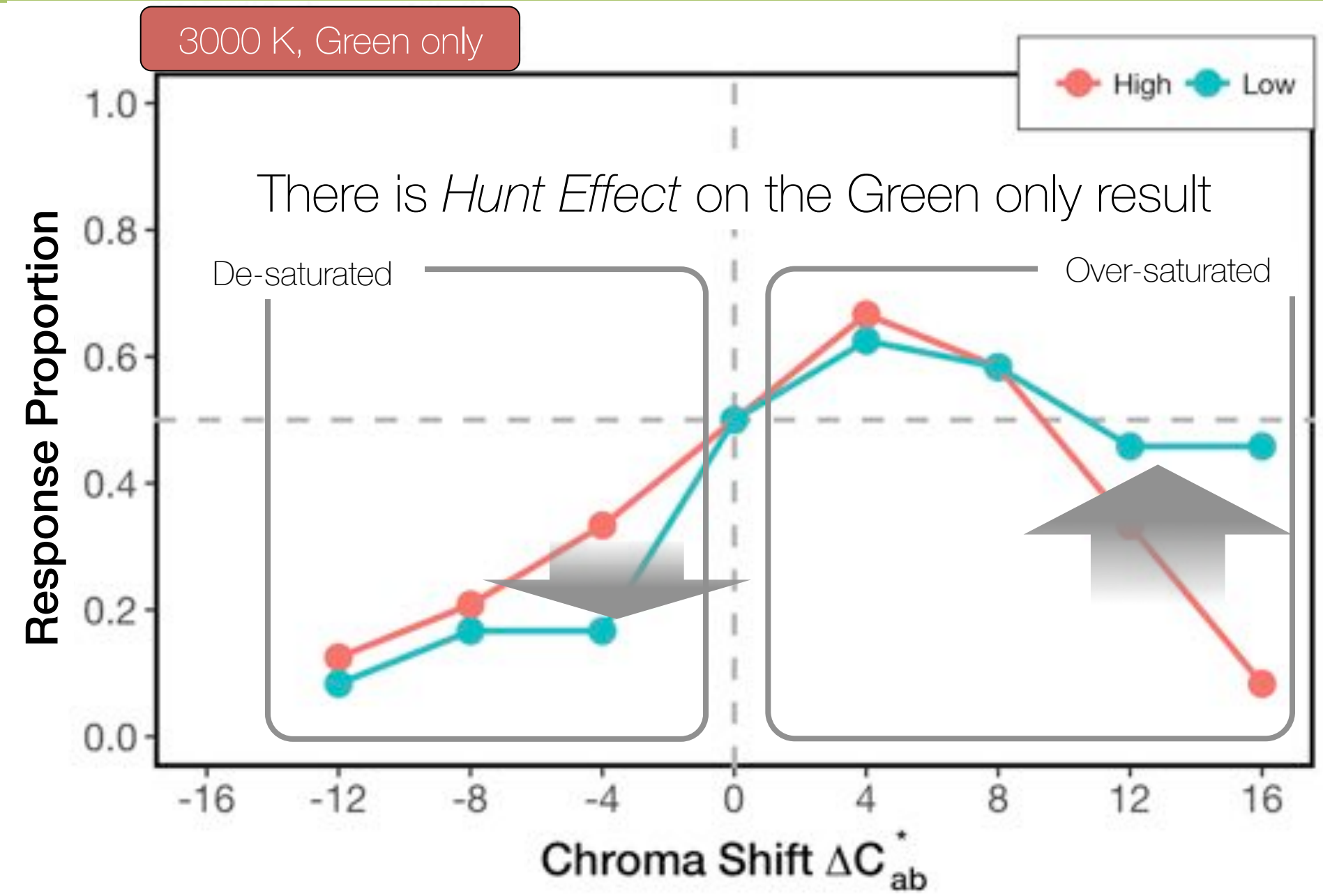
Result


5000 K, Mix
High
Low
Peaks
Response Proportion
1.0
0.8
0.6
0.4
0.2
0.0
-16
-12
-8
-4
0
4
8
12
16
Chroma Shift ΔC*ab

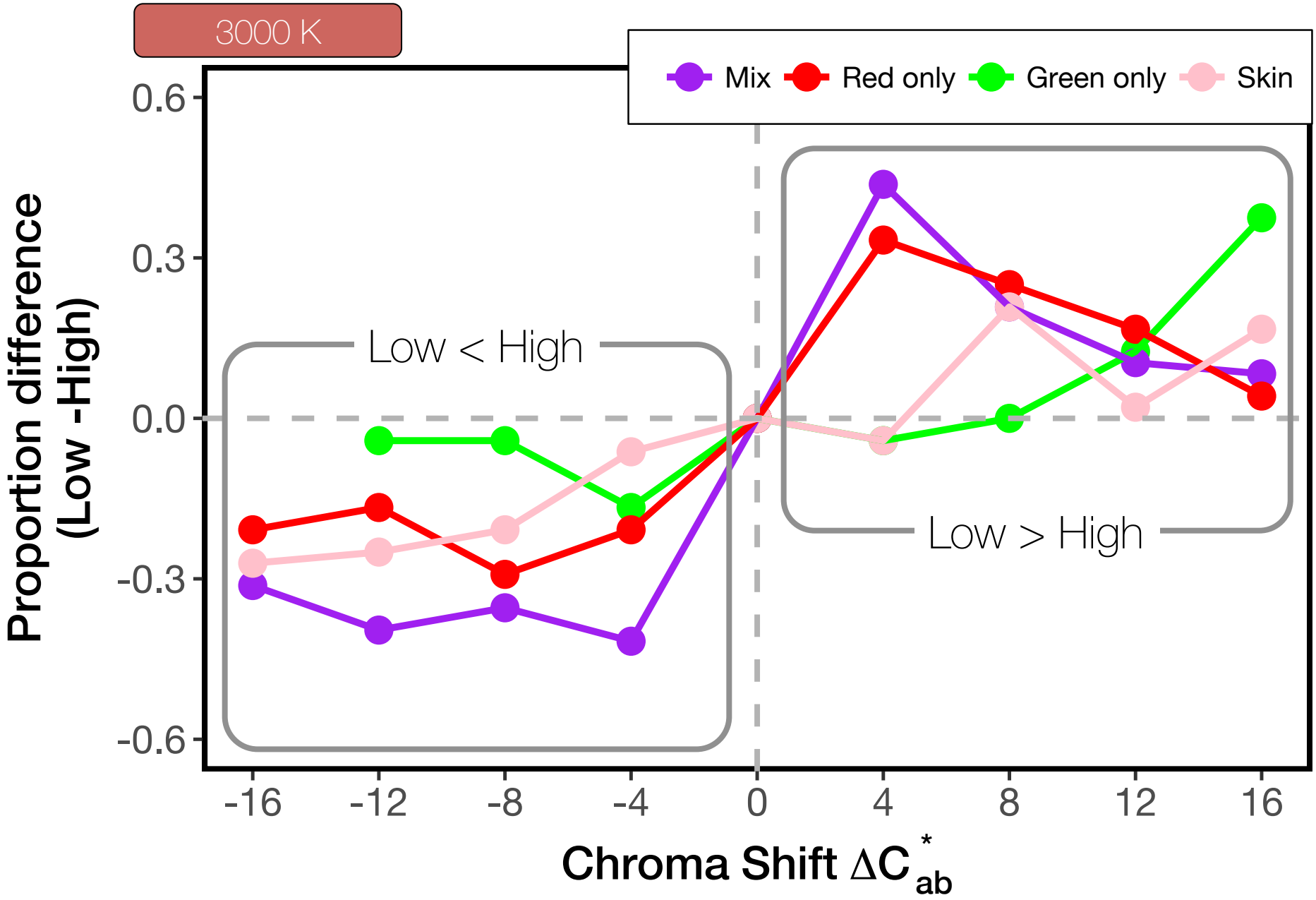
Result


5000 K, Skin
High
Low
Peaks
Response Proportion
1.0
0.8
0.6
0.4
0.2
0.0
-16
-12
-8
-4
0
4
8
12
16
Chroma Shift ΔC*ab

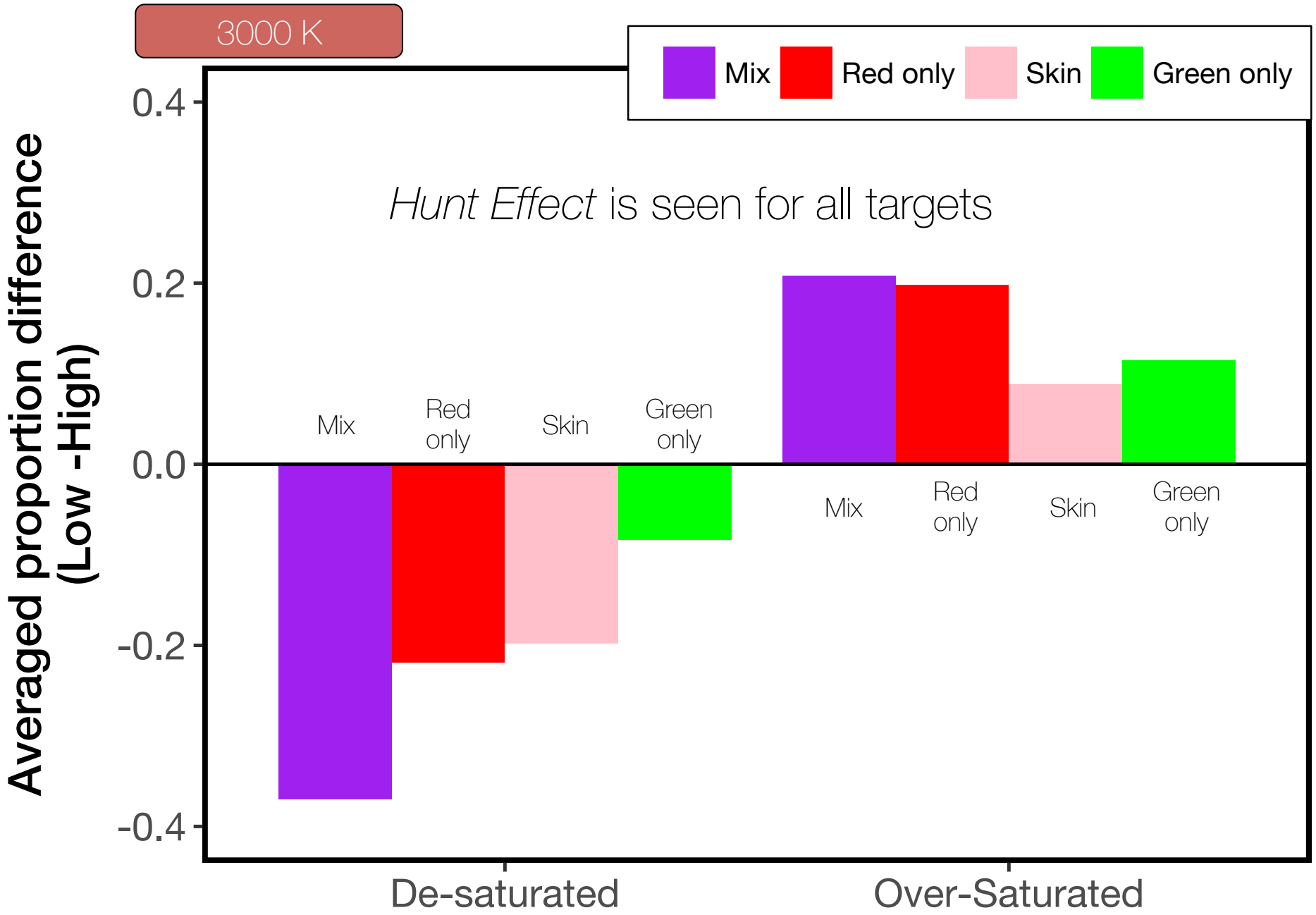
Discussion - Effects other than peak shift



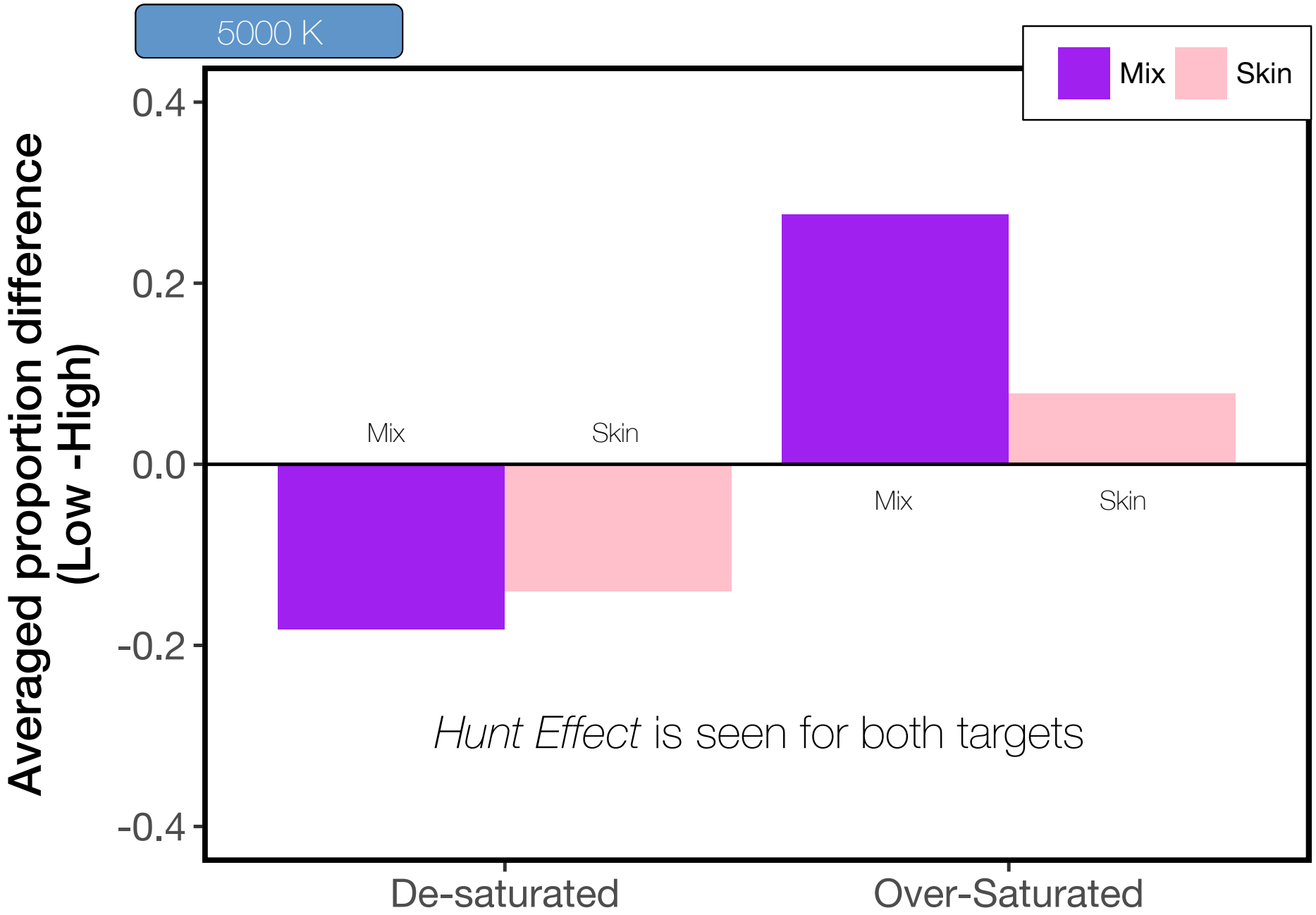
Discussion


3000 K
Mix
Red only
Green only
Skin
0.6
0.3
0.0
-0.3
-0.6
Proportion difference
(Low -High)
Low < High
Low > High
-16
-12
-8
-4
0
4
8
12
16
Chroma Shift ΔC*ab

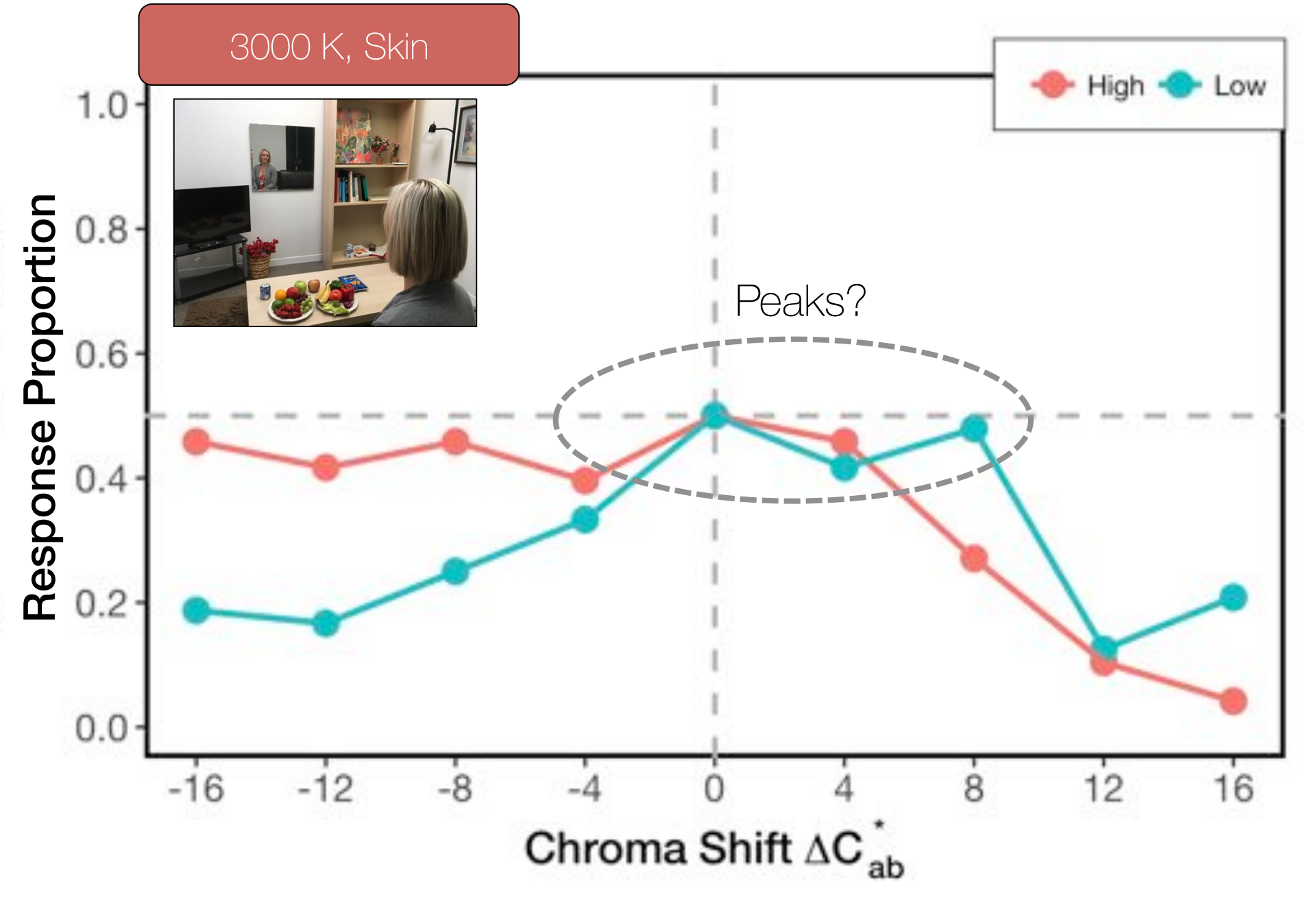
Discussion


3000 K
Mix
Red only
Skin
Green only
Hunt Effect is seen for all targets
Averaged proportion difference (Low -High)
0.4
0.2
0.0
-0.2
-0.4
Mix
Red only
Skin
Green only
Mix
Red only
Skin
Green only
De-saturated
Over-Saturated

Discussion


5000 K
Mix
Skin
0.4
0.2
0.0
-0.2
-0.4
Averaged proportion difference
(Low -High)
Mix
Skin
Mix
Skin
Hunt Effect is seen for both targets
De-saturated
Over-Saturated

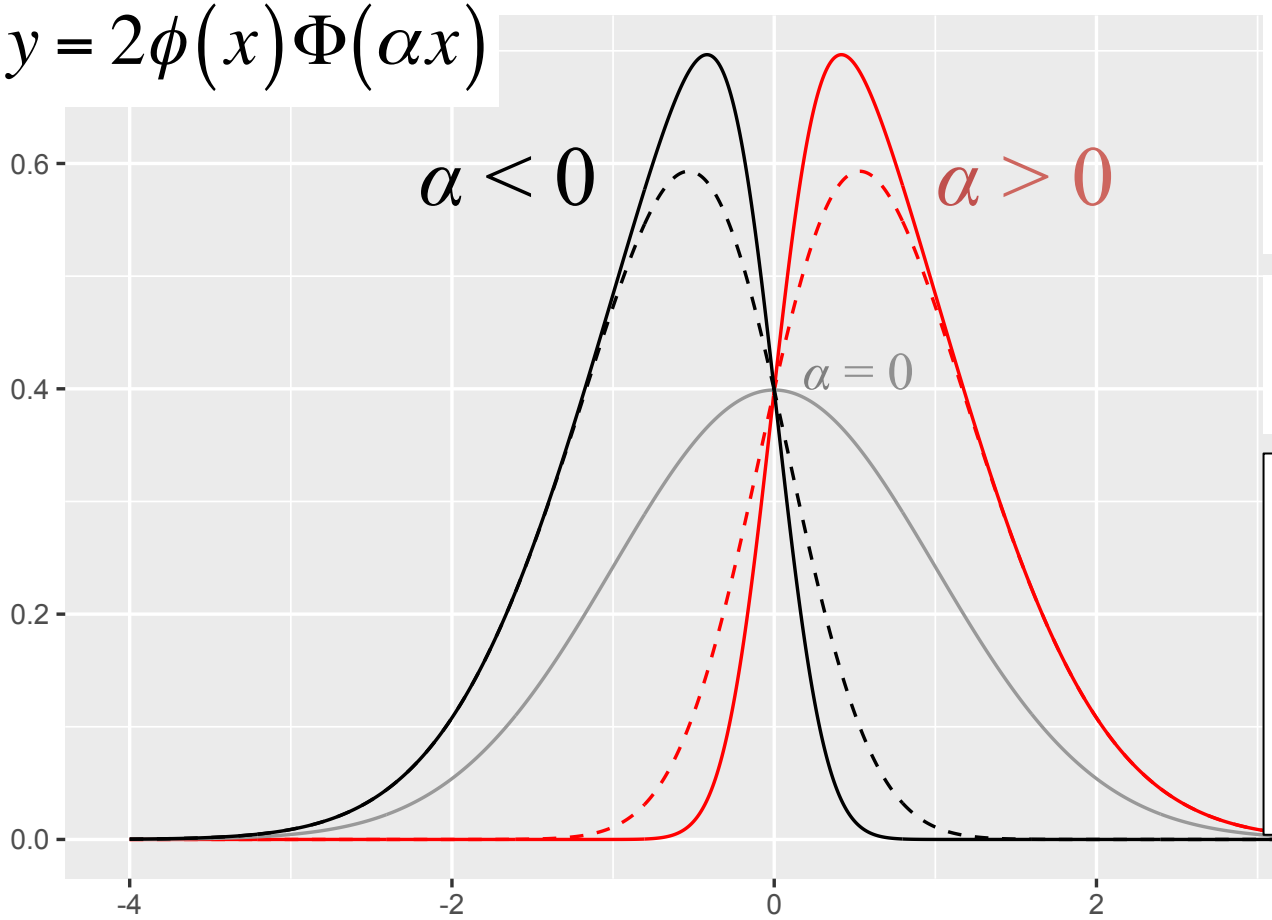
Discussion - Fitting model



Discussion - Fitting model

$$f(x) = M \times \frac{2}{\omega}\phi\left(\frac{x-\xi}{\omega}\right)\Phi\left(\alpha\left(\frac{x-\xi}{\omega}\right)\right)$$

$$y = 2\phi(x)\Phi(\alpha x)$$

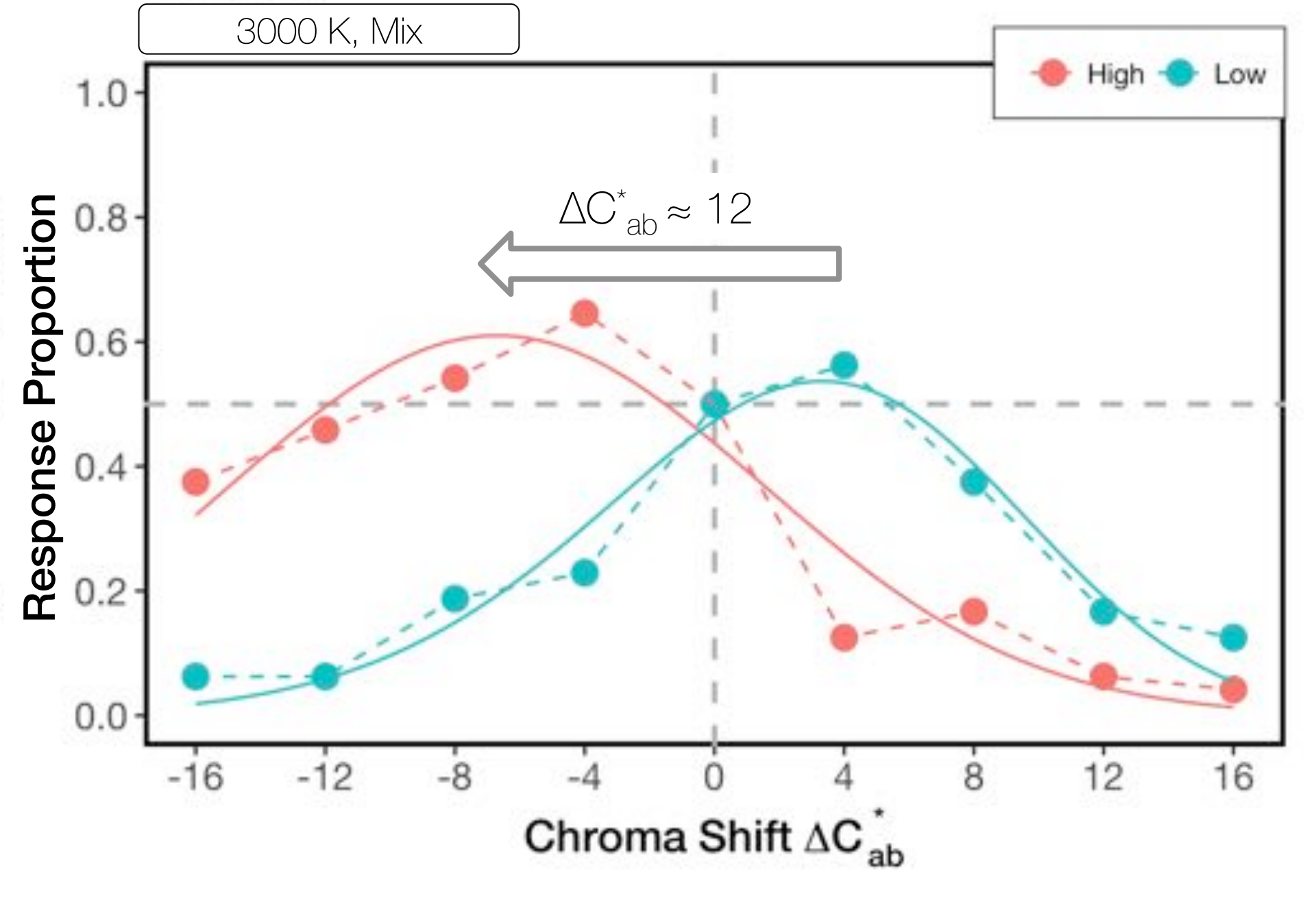


$$\phi(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$$

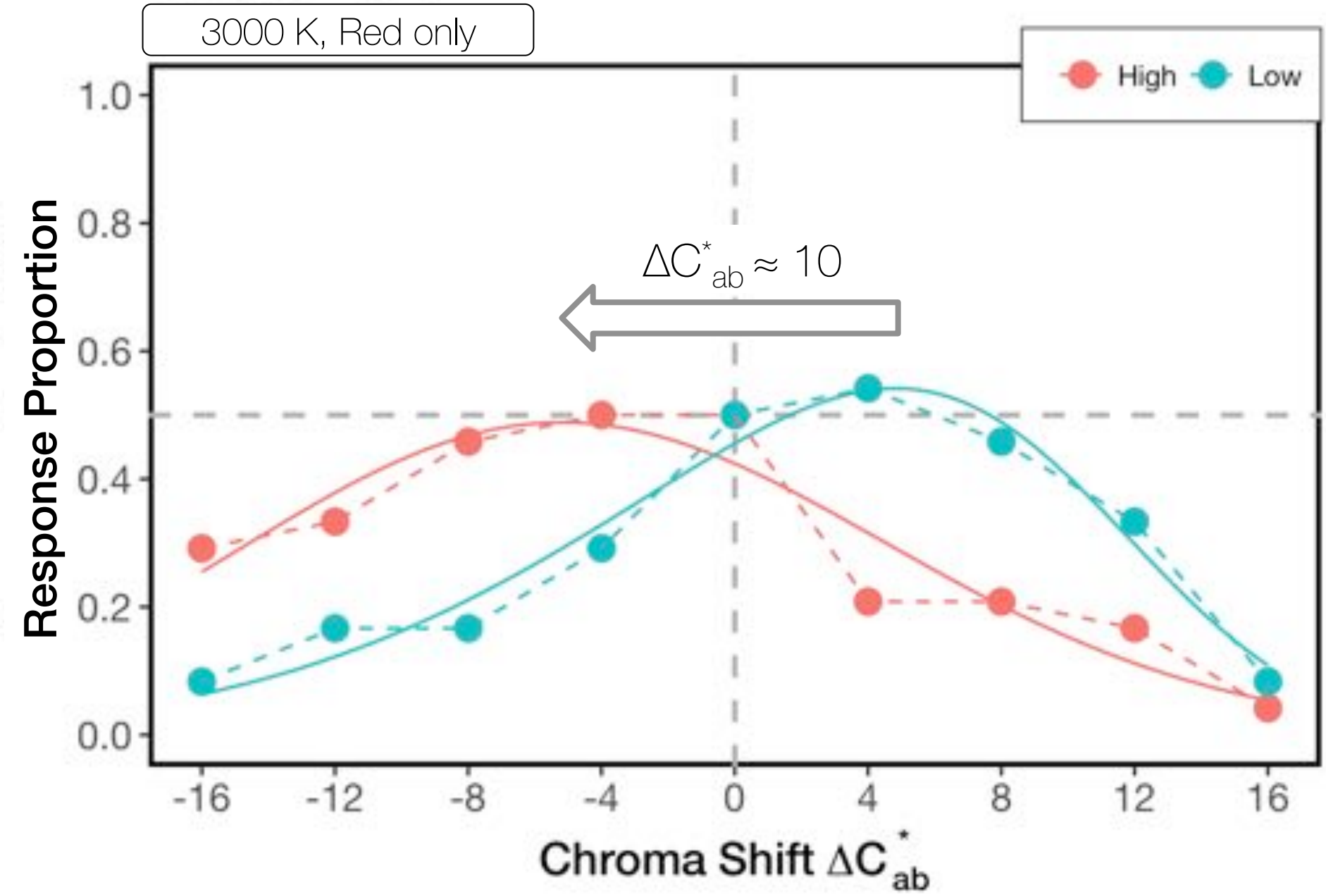
$$\Phi(x) = \int_{-\infty}^{x} \phi(t)\,dt$$

M : magnitude
α : asymmetry
ξ : position shift
ω : width

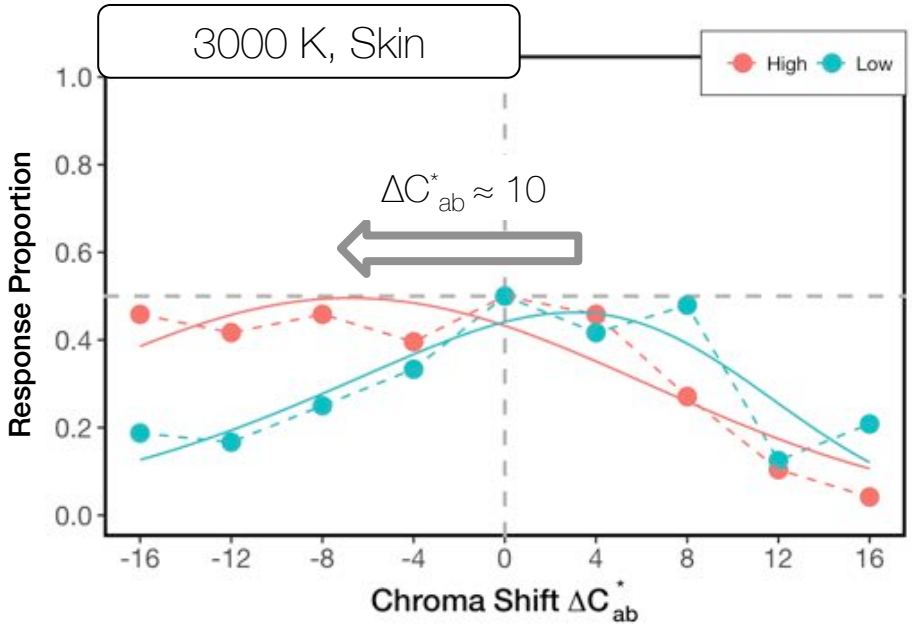
Discussion - Fitting results

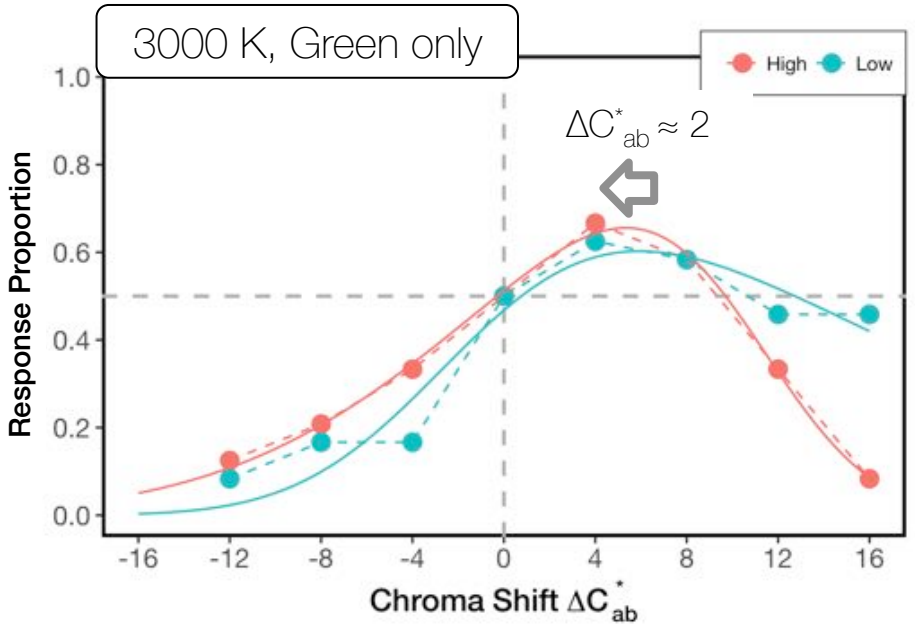


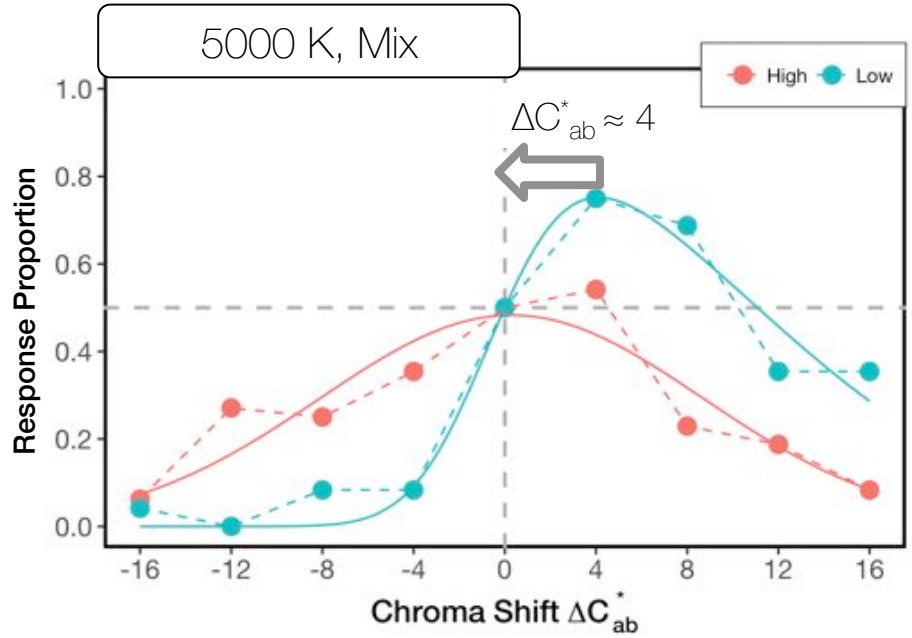
Discussion

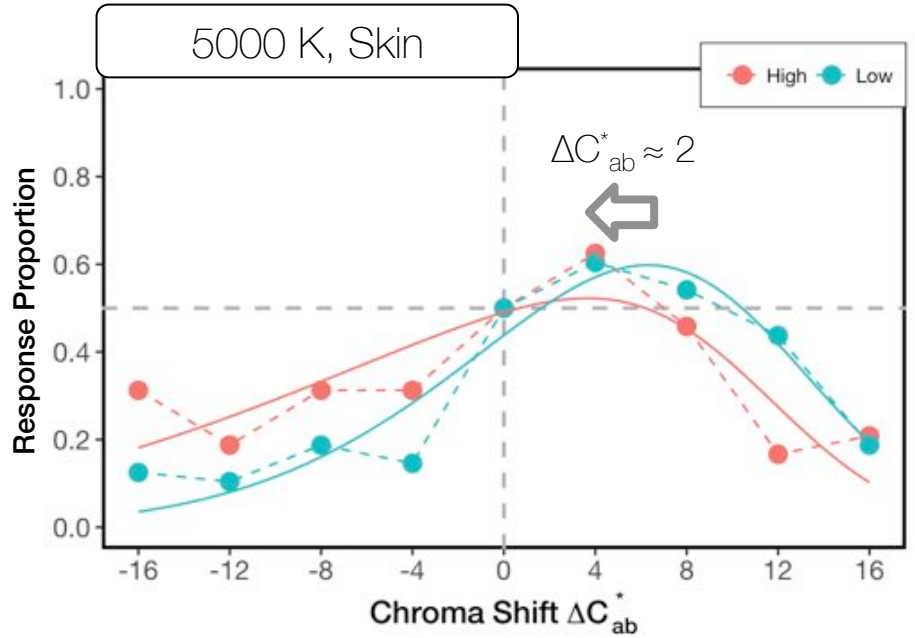

3000 K, Red only
High
Low
$\Delta C^*_{ab} \approx 10$
Response Proportion
1.0
0.8
0.6
0.4
0.2
0.0
-16
-12
-8
-4
0
4
8
12
16
Chroma Shift ΔC^*_{ab}

Discussion


3000 K, Skin
High
Low
$\Delta C^*_{ab} \approx 10$
Response Proportion
Chroma Shift ΔC^*_{ab}


3000 K, Green only
High
Low
$\Delta C^*_{ab} \approx 2$
Response Proportion
Chroma Shift ΔC^*_{ab}


5000 K, Mix
High
Low
$\Delta C^*_{ab} \approx 4$
Response Proportion
Chroma Shift ΔC^*_{ab}


5000 K, Skin
High
Low
$\Delta C^*_{ab} \approx 2$
Response Proportion
Chroma Shift ΔC^*_{ab}

Conclusions

- The experimental results verified that *Hunt Effect* is effective at typical indoor lighting conditions
- The experiments were done by direct viewing of typical objects (not haploscopic viewing condition)
- There are shifts in the peak of the chroma level that looked most natural (by ΔC^*_{ab} 2 to 10 in the result, for 1000 to 100 lx)
- Effectiveness of Hunt Effect was shown not only the peak shift but also in the shapes of probability curves
- Slightly increased chroma may bring the perceived object colors close to those under outside daylight
- **The effect of chroma shift is not only for preference/ naturalness issue but also an issue for color fidelity**

Thank you for your attention

Contact: yuki.kawashima@nist.gov