IV. chromatic adaptation

adjustment to changes in color of illuminant

related to light/dark adaptation

mechanisms (physiological)

1. pupil size (5X change in luminance)

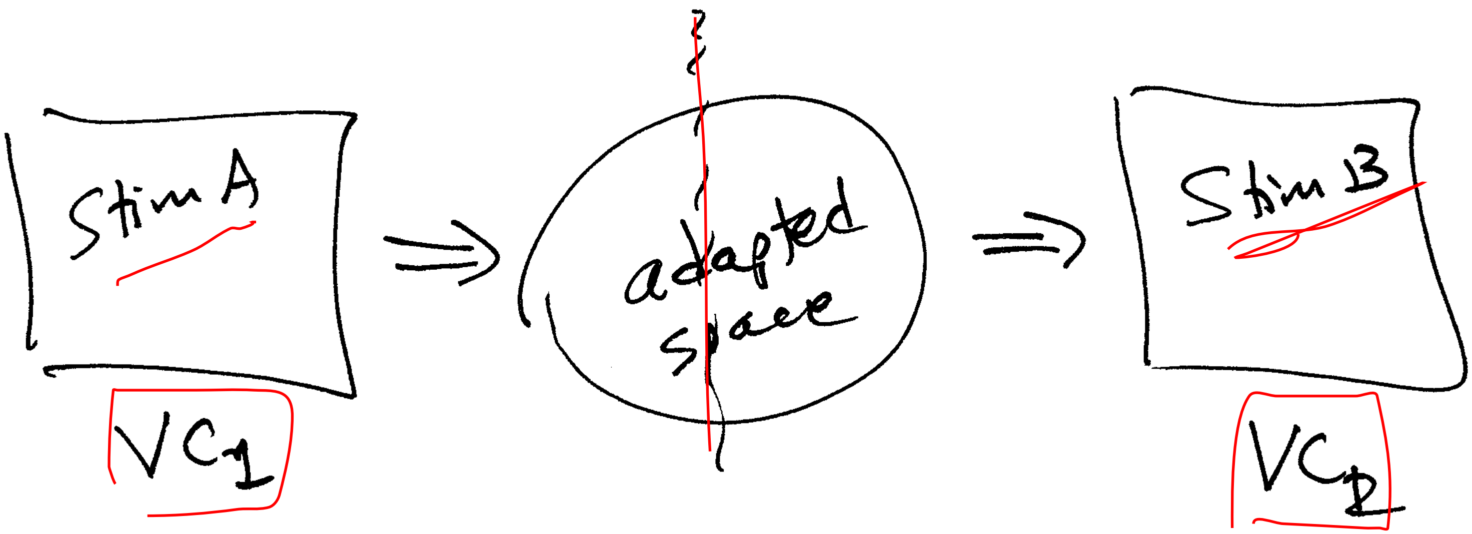
$$\frac{\text{lum. bright daylight}}{\text{lum. starlight}} = 10^{10}$$

2. rod/cone

3. receptor gain control

von-Kries' adaptation

predict corresponding colors



SA & VC_1 & VC_2 are given
What Stim B will match Stim A?

$\cancel{\begin{bmatrix}X\\Y\\Z\end{bmatrix}}$ $\begin{bmatrix}L\\M\\S\end{bmatrix}$.

Model is based on adjusting receptor gains ⟹ need to work in receptor space, i.e. cone outputs

$$\begin{pmatrix} L \\ M \\ S \end{pmatrix} = \underbrace{\begin{bmatrix} 0.4 & 0.7 & -0.08 \\ -0.2 & 1.2 & 0.05 \\ 0.0 & 0.0 & 0.9 \end{bmatrix}}_{\underline{M}} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

cone space

CIE

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix}_{adapt} = \begin{bmatrix} a_L & 0 & 0 \\ 0 & a_M & 0 \\ 0 & 0 & a_S \end{bmatrix} \begin{bmatrix} L \\ M \\ S \end{bmatrix}_{VC_1}$$

$a_L = \dfrac{1}{L_W}$ — white pt. $\quad a_S = \dfrac{1}{S_W}$

$a_M = \dfrac{1}{M_W}$

Chromatic Adaptation Transform (CAT) (13)

$$\underset{\text{VC\_2}}{\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}} = \underline{M}^{-1} \begin{bmatrix} L_{W_2} & & \\ & M_{W_2} & \\ & & S_{W_2} \end{bmatrix} \begin{bmatrix} 1/L_{W_1} & & \\ & 1/L_{W_2} & \\ & & 1/L_{W_3} \end{bmatrix} \cdot \underline{M} \underset{\text{VC\_1}}{\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}}$$

B   adapted state   A

L_W_2 M_W_2 S_W_2   L_W_1   M_W_1   S_W_1   L_W_1 M_W_1 S_W_1   VC_1   VC_2

Nayatani's model

nonlinear model

$$L_{adapt} = a_{L_A} \left(\frac{L_A + L_n}{L_{W_A} + L_n} \right)^{\beta_{L_A}}$$

noise term

exponent depends on VC luminance level

Stevens power law

to ~~...~~ go from adapted state to VC_2 invert model:

$$L_B = \frac{1}{a_{L_B}} \left(L_{adapt}^{1/\beta_{L_A}} \right) \left(L_{W_B} + L_{n_B} \right) - L_{n_B}$$

models over-predicts adaptation

Fairchild's model

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix}_{adapt} = \begin{bmatrix} a_L^A & & 0 \\ & a_M^A & \\ 0 & & a_S^A \end{bmatrix} \begin{bmatrix} L \\ M \\ S \end{bmatrix}_A$$

Similar equations for a_M^A and a_S^A

upper case in some places in text

"n" in text

$$a_L^A = \frac{p_L^A}{L_{W_A}}$$

text = Handbook of Digital Color Imaging, G. Sharma, ed.

$$p_L^A = \frac{1 + Y_{W_A}^{1/3} + l_E}{1 + Y_{W_A}^{1/3} + 1/l_E}$$

Y_W_A - absolute adapting luminance

wrong in text

$$l_E = \frac{3 L_{W_A}/L_E}{L_{W_A}/L_E + M_{W_A}/M_E + S_{W_A}/S_E}$$

Discussion

1. If $p_L^A = 1 \Rightarrow$ von Kries "complete adaptation"

2. If $p_L^A = L_{WA} \Rightarrow$ no adaptation

3. ~~E~~ E – equal energy illuminant

4. ℓ_E – ~~a~~ "like" a chromaticity

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix}_{\text{adapt}} = \begin{bmatrix} a_L^A & 0 & 0 \\ 0 & a_M^A & 0 \\ 0 & 0 & a_S^A \end{bmatrix} \begin{bmatrix} L \\ M \\ S \end{bmatrix}_A$$

$$a_L^A = \frac{p_L^A}{L_{W_A}}$$

$$p_L^A = \frac{1 + Y_{W_A}^{1/3} + \ell_E}{1 + Y_{W_A}^{1/3} + 1/\ell_E}$$

$$\ell_E = \frac{3L_{W_A}/L_E}{L_{W_A}/L_E + M_{W_A}/M_E + S_{W_A}/S_E}$$

$$0 \le \ell_E \le 3$$

0 ↑ blue-green yellow stimuli

3 → really red stimulus

5. p_L^A — for any fixed ℓ_E, making Y_{W_A} ~~…~~ larger drives $p_L^A \to 1$

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix}_{adap.} = \begin{bmatrix} a_L^A & 0 & 0 \\ 0 & a_M^A & 0 \\ 0 & 0 & a_S^A \end{bmatrix} \begin{bmatrix} L \\ M \\ S \end{bmatrix}_A$$

$$a_L^A = \frac{p_L^A}{L_{W_A}}$$

$$p_L^A = \frac{1 + Y_{W_A}^{1/3} + \ell_E}{1 + Y_{W_A}^{1/3} + 1/\ell_E}$$

$$\ell_E = \frac{3L_{W_A}/L_E}{L_{W_A}/L_E + M_{W_A}/M_E + S_{W_A}/S_E}$$

$\Rightarrow$ adaptation is most complete for large Y_{WA}

$\Rightarrow$ minimal adaptation for limiting case as $Y_{WA} \to 0$

$$p_L^A = \frac{1 + l_E}{1 + 1/l_E} = \underline{l_E}$$

but no response

$l_E = 0 \Rightarrow p_L^A = 0 \Rightarrow$ ~~complete adaptation~~ ?

$l_E = 3 \Rightarrow p_L^A = \frac{1 + 3}{1 + 1/3} = 3$

max. extent of incomplete adaptation

For incomplete adaptation want $a_L^A \cong 1$

$\Rightarrow$ incomplete adaptation is most important in dim viewing conditions