Appendix

A.1 Linear Transformations

In this section, we list the five different matrices that were used in our analysis to characterize linear transformations between XYZ and opponent-channel responses.

1. Zhang [9]

$$\begin{bmatrix} O_1 \\ O_2 \\ O_3 \end{bmatrix} = \begin{bmatrix} 0.2790 & 0.7200 & -0.1070 \\ 0.4490 & -0.2900 & 0.0770 \\ 0.0860 & -0.5900 & 0.5010 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{2}$$

2. Hurvich [10]

$$\begin{bmatrix} O_1 \\ O_2 \\ O_3 \end{bmatrix} = \begin{bmatrix} 0.0000 & 1.0000 & 0.0000 \\ 1.0000 & -1.0000 & 0.0000 \\ 0.0000 & 0.4000 & -0.4000 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{3}$$

3. Flohr [11]

$$\begin{bmatrix} O_1 \\ O_2 \\ O_3 \end{bmatrix} = \begin{bmatrix} 0.0000 & 1.1600 & 0.0000 \\ 5.0000 & -5.0000 & 0.0000 \\ 0.0000 & 2.0000 & -2.0000 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} - \begin{bmatrix} 16 \\ 0 \\ 0 \end{bmatrix} \tag{4}$$

4. Hunt [12-14]: XYZ to OPP is determined by combining two matrices (Eq. (5) and Eq. (6)).

$$\begin{bmatrix} O_1 \\ O_2 \\ O_3 \end{bmatrix} = \begin{bmatrix} 2.0000 & 1.0000 & 0.0500 \\ 1.0000 & -1.0900 & 0.0900 \\ 0.1100 & 0.1100 & -0.2200 \end{bmatrix} \begin{bmatrix} L \\ M \\ S \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 0.3897 & 0.6890 & -0.0787 \\ -0.2298 & 1.1834 & 0.0464 \\ 0.0000 & 0.0000 & 1.0000 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{6}$$

5. Wandell [14, 15]: XYZ to OPP is also determined by combining two matrices (Eq. (7) and Eq. (6)).

$$\begin{bmatrix} O_1 \\ O_2 \\ O_3 \end{bmatrix} = \begin{bmatrix} 1.0000 & 0.0000 & 0.0000 \\ -0.5900 & 0.8000 & -0.1200 \\ -0.3400 & -0.1100 & 0.9300 \end{bmatrix} \begin{bmatrix} L \\ M \\ S \end{bmatrix} \tag{7}$$

A.2 The Effect of Luminance

In our experiment, the luminance of the stimulus was different for different hues and saturations. A question arises as to whether luminance changes affected the unique hue settings. To evaluate this effect, we performed a control experiment in which one subject (SL) was tested. One stimulus for each unique hue was chosen. These were SL's unique hues that were found in the main experiment. Each color had a medium saturation level. SL ran four sessions (red, green, blue, yellow) with six trials in each session. Within a session, six stimuli were generated with different levels of luminance. These were presented in random order. The subject's task was again to make the patch look unique by adjusting the slide-bar. Figure 11 shows the variation of chromaticity x and y as the luminance increases for each color. It seems that there is no (or little) effect of luminance. These results are consistent with the Bezold-Brücke hue shift as measured with monochromatic lights and with results of Larimer et al.[6, 7] using a combination of monochromatic wavelengths.

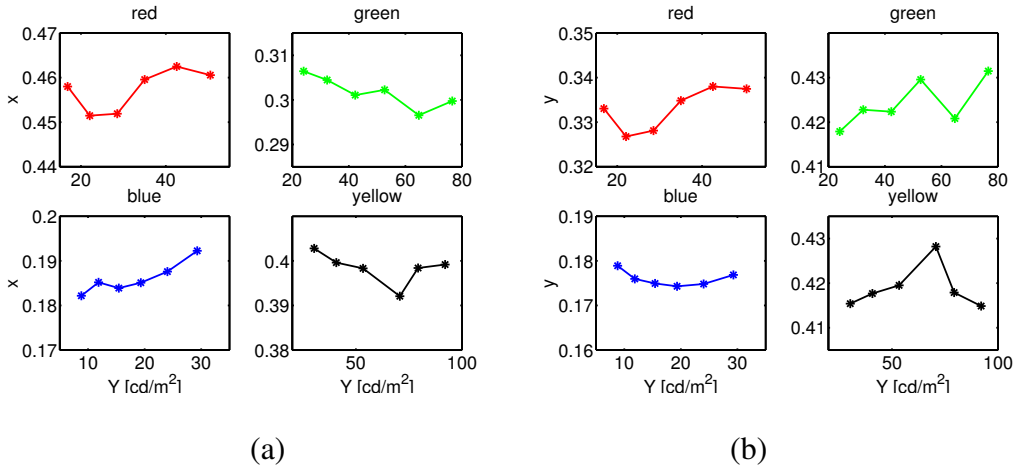

Figure 11. Subject SL's settings of unique hues (medium saturation) at different levels of luminance: (a) variation in chromaticity x and (b) variation in chromaticity y.