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Color Perception Tied to Natural Environment

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1. Introduction

It was talked about two researches which took quite different approaches, but both implied that color coding of our visual system was formed and influenced by natural environments.

2. Seasonal variations in the color statistics of natural images[1]

2.1 Introduction

Models of visual coding based on natural scene statistics depend on identifying regularities in the environment. However, the color characteristics of natural scenes can vary widely both across different environments[2] and within the same environment over time because of seasonal changes. We compared these seasonal variations in two very different outdoor environments: tropical forest and grasslands in the Western Ghats of India and alpine forest and meadows in the northern Sierras. Images of outdoor scenes were acquired in India, during monsoon and winter seasons and in USA, from spring to fall.

2.2 Analysis

Estimated L, M, and S cone excitations, and chromatic and luminance contrasts were compared. Seasonal changes alter both the average color and the color distribution in scenes. Illumination color was estimated from the spectroradiometric measurements of a white chip and the contribution of illumination to the seasonal changes was also examined.

2.3 Results and discussion

Fig. 1 shows the mean color of each image plotted in MacLeod-Boynton chromaticity diagram. Vegetation changes between monsoon and winter seasons in India shift the average chromaticity of scenes from green to yellow. Seasonal variations in the Sierra images were weaker but followed a similar pattern. In both cases the mean color shifts are largely along an

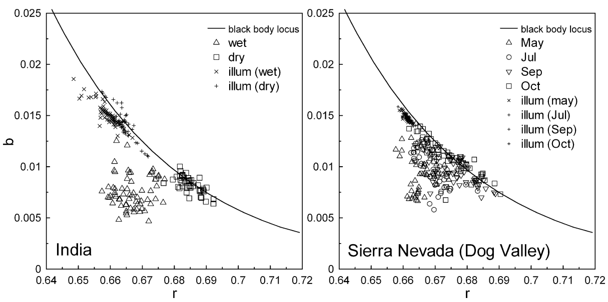

Fig. 1. Color distribution on MacLeod-Boynton chromaticity diagram. Mean color of each image and its illumination in India (left) and Sierra (right).

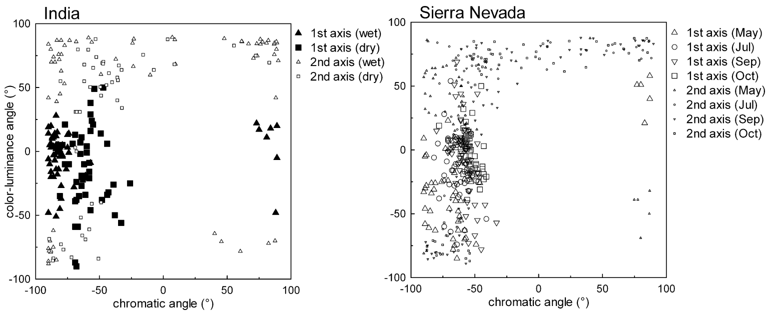

Fig. 2. The principal axes of the distributions for each image in India (left) and the Sierras (right). The chromatic angle gives the axis in a scaled-version of the MacLeod-Boynton chromaticity diagram[2]. −90 deg corresponds to variations along the S axis, 0 deg to the L–M axis and −45 deg to a blue-yellow variation. The color-luminance axis gives the angle at which scenes tended to vary out of the isoluminant plane (0 deg).

L–M(r) axis, implying that this axis captures the general the "lushness" of an environment. This similarity in the two locations suggests a characteristic pattern of temporal variation of color statistics that might shape color coding. As the environment becomes more arid the distributions shift along the +L axis. This color change is similar to the +L shift that allows ripening fruit or edible leaves to be distinguished from the background foliage[3]. The distribution of illuminant chromaticities is very similar across the different seasons. Thus the large changes in the mean color of the scenes across seasons are due to changes in the reflectance properties of the scenes.

Fig. 2 shows the principal axes of the distributions in each scene. They rotate from roughly an S-cone varying axis to a blue-yellow axis (wet→dry) in the India images. Those in the Sierra images were also weaker but followed a similar pattern. This rotation is consistent with previous measurements of scenes sampled from different environments[2]. However, the principal axes in the Sierra images also rotate along color-luminance angle. Rotations in the color distributions provide a further correlate of lushness, but imply that in many contexts the color distributions are not well described by independent variations along the S and L–M axes.

While natural color distributions are context dependent, the fact that the variations themselves show characteristic properties suggests important regularities in the color environment that might shape color coding.

3. Color appearance affected by naturalness of environment[4]

3.1 Introduction

Color constancy is often explained by mechanisms in lower levels of the visual process such as an adaptation of photoreceptor on the retina and adaptation to the averaged color of a visual field. However, the recognition of spatial structure is important for color constancy[5]. We have no difficulty on recognizing objects' color since we can recognize a space and illumination naturally in normal environments with three-dimensional structure. What happens if we were thrown into an unnatural environment? We might not be able to construct those recognitions correctly and fail to have color constancy. We examined how color constancy was affected by an unnatural viewing condition where the spatial structure was distorted.

3.2 Experiments

In Single-room condition, a small room was illuminated by incandescent type fluorescent lamps with color temperature of 3000 K as shown in **Fig. 3**(a). In Two-room condition, an additional room was connected in the back of the room and illuminated by white (5000 K) lamps (Fig. 3(b)). An observer viewed both rooms at the same time through a window on a wall between the back and the front room.

In the natural viewing condition, the observer viewed inside through an aperture on a viewing box and judged the color of a 2 degree test patch in the center of the room. Test patches were placed in either back or front room.

In the unnatural viewing condition the aperture was replaced by a kaleidoscope made of three rectangular mirrors arranged in an equilateral triangle (Fig. 3(c)). The spatial structure of the room was jumbled due to reflections from the mirrors, while the test patch and its adjacent surround were the same. The field of view and the averaged color of the visual field were roughly the same in both viewing conditions. Neutral perception for each condition was measured by color judgments of a series of the patches with colors along the black body locus.

3.3 Results

Fig. 4 shows the results from three observers under all conditions. The results of Single-room condition show that neutral points of both viewing conditions are similar and close to the illumination color of the front room, meaning the high degree of color constancy. This suggests that illumination color can be recognized even if the spatial structure is jumbled in the case of the environment with single illumination.

In Two-room condition, on the other hand, a

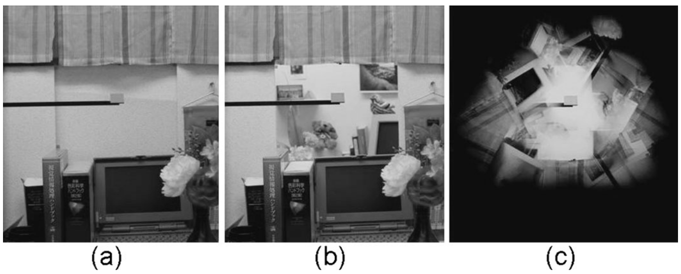

Fig. 3. Examples of view from an observer. (a) Single-room condition (natural view). (b) Two-room condition (natural view). (c) Unnatural viewing condition at Two-room condition.

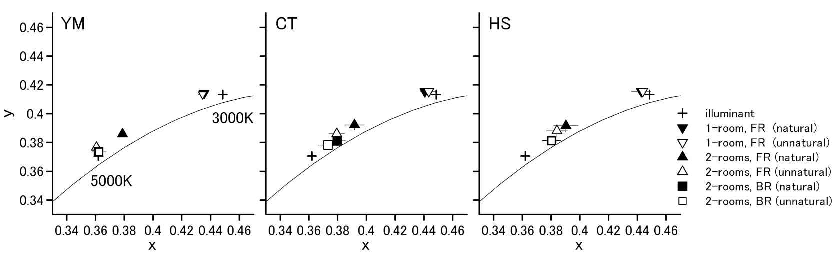

Fig. 4. Results from 3 observers on xy chromaticity diagram. Filled and open symbols indicate natural and unnatural viewing condition, respectively. Standard deviations are shown by error bars. Inverted triangles, front room in Single-room condition; triangles, front room in Two-room condition; squares, back room in Two-room condition.

neutral point for the front room shifts further from its illumination color under the unnatural viewing condition compared to the natural one. The degree of constancy for the front room decreased in this case, suggesting that observers could not locate which room test patches were in, and those colors were judged mainly based on the immediate background (i.e. the wall of the back room).

The results suggest that naturalness and spatial factors play important roles on color constancy in a complex environment such as a space with multiple illuminations.

4. Summary

It was shown that different aspects of interaction between color appearance and environment.

The characteristic seasonal variation suggests that the development of our color coding mechanism might have been shaped by the color variations of the natural environment. The result showing color constancy affected by viewing conditions implies that our constancy mechanism is optimized to the natural 'viewing' environment where we can establish space and illumination recognition. Both researches suggest that color perception is closely tied to the natural environment.

References

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