Color appearance is determined by the recognition of a 3D space

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ABSTRACT

We showed that the color appearance is determined by the adaptation to the room illumination and not by the retinal chromatic adaptation. The color appearance of a test patch placed in a test room was judged through a window of which size was variable. Whenever a subject saw objects in the room beside the test patch, the color appearance suddenly changed showing the color constancy for the room. The color appearance was not affected by the color of the objects surrounding the test patch, red or green, but it was determined by the color of illumination in the test room.

1. INTRODUCTION

We live in a 3D space and not on a 2D plane. The most important function of our brain is to understand about the 3D space surrounding us. Among others the illumination in the space is certainly one of the most important understanding because we cannot recognize the color of objects and light in the space without the understanding about how much and what kind of illumination is in the space. The understanding of a space and the illumination there is realized by recognizing the objects in the space, which we called the initial visual information.[1,2)] When the understanding was established in us, we expressed the situation that the recognized visual space of illumination RVSI was constructed in our brain.[3,4)] In the first experiment we changed the initial visual information about the space to which a test patch belonged and showed that the perception of the correct color appearance of the patch was achieved when a subject recognized the existence of the space. The retinal chromatic adaptation did not play an important part in the perception. In the second experiment we changed the retinal chromatic adaptation and showed that the change was not effective for the color perception of a test patch.

2. EXPERIMENT 1

The experimental booth was made of a subject room and a test room separated by a wall with a window through which a subject saw monocularly the test room. Both rooms were decorated with various objects such as dolls, books, real flowers, and wooden blocks to simulate normal situation. The subject room was illuminated by fluorescent lamps of daylight type covered by one of the color films, red, yellow, green or blue at 30 lx on the table in front of the subject, and the test room by the same lamps but without any film at 25 lx when measured vertically in front of the test patch. In the test room the test patch of the size 8 cm x 8 cm was placed vertically. Five different colors were employed for the test patch, 5R5/3,

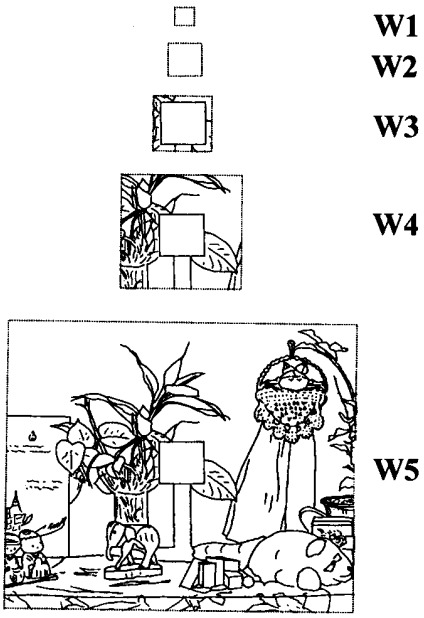

Fig. 1 Views of the test room through windows of various sizes.

5Y5/3, 5G5/3, 5B5/3 and N5.

The window size was changeable quickly by replacing the window frame to one of five different sizes and the subject saw different extents of the test room as shown in Fig. 1. A square at the center is the test patch of which color the subject judged by the elementary color naming method. With small windows W1 and W2 only the test patch was seen through the window and the patch appeared as if it was pasted on the window. The color appearance must be determined in relation to the RVSI constructed for the subject room in this case. If the subject room is illuminated by the red light the subject's visual system adapts to the room illumination. According to the concept of the RVSI this means that the recognition axis on which the color appearance is neutral or achromatic locates in a red side. The test patch should appear greenish if the patch is originally achromatic. With the window W3 the subject could see pieces of green leaves placed in the test room and he/she could recognize the existence of the test room and constructs another RVSI for the test room illuminated by white light. The color appearance of the test patch should return to its original color. No more color change should take place for larger windows W4 and W5. Four subjects participated in the first experiment.

3. RESULTS OF EXPERIMENT 1

The results from the green and red illumination of the subject room are shown in Fig. 2 by an ordinary polar coordinate for the elementary color naming. Data points are averages of four subjects. Large filled squares indicate the color appearance of the illumination of the subject room when judged from outside the subject room. Different symbols indicate test patches; squares for 5R5/3, triangles for 5Y5/3, diamonds for 5G5/3, x for 5B5/3 and circles for N5. In the case of red illumination the first points locating at the extreme left side of all the test patches were obtained from W1. Their color appearance is vivid bluish green or greenish blue. It is clear the color appearance was decided based on the RVSI adapted to the red illumination of the subject room. The second points obtained from W2 locate very close to the first points. The most important result is that the color appearance suddenly changed to return to their original colors that were obtained in a control experiment, though not shown here, at the third points with W3. As soon as the subjects recognized the existence of the test room beyond the window the color appearance of the test patches returned to their original color or the color constancy took place. Fig. 3 shows the distance of each point from the original color point in Fig. 2. A sudden drop is clearly seen in each curve from W2 toW3 and the recovery to the original color or the completion of the color constancy for the test room took place almost with W3. It is hard to think the retinal chromatic adaptation as the cause for the drop. Only a little change in the retinal adaptation takes place from W2 to W3 as supposed from Fig. 1.

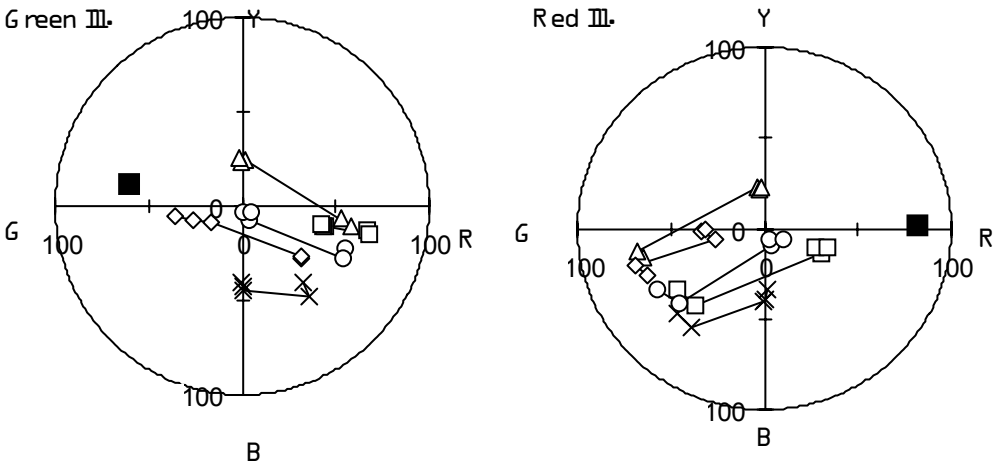

Fig. 2 Change of color appearance of test patches with different window size. Left, green illumination of the subject room; right red illumination. □,5R; □,5Y; □,5G; ×,5B; ○,5N.

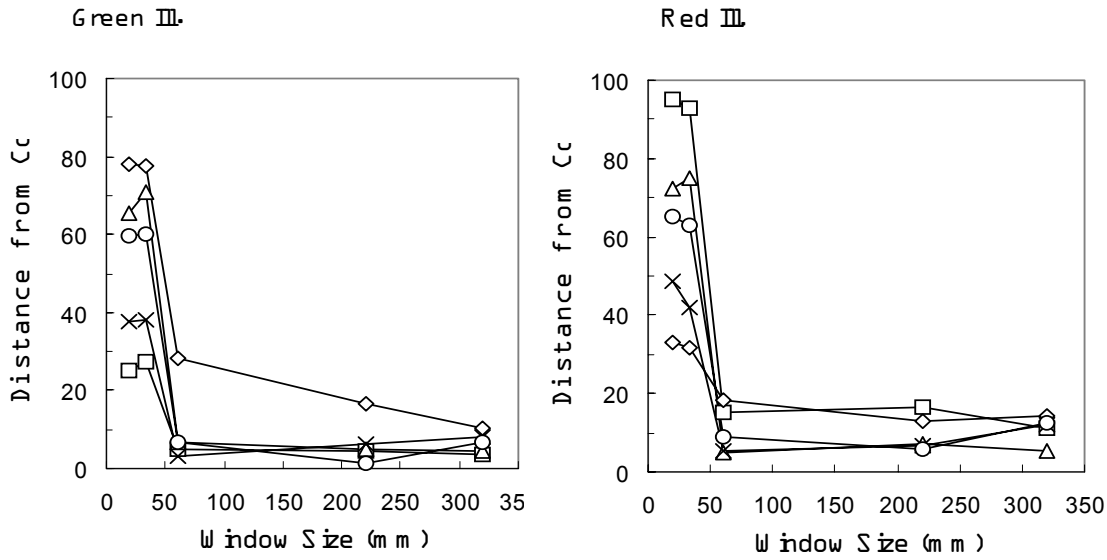

Fig. 3 Change of color appearance of test patches with window size expressed by the distance from the data points to the original color in Fig. 2. Left, green illumination of the subject room; right red illumination.

4. EXPERIMENT 2

The results of the experiment 1 showed that the recovery of the color appearance of the test patch took place based on the recognition of the test room as a 3D space different from the subject room. We can say then that the color appearance of the test patch was determined by the action of the brain and not by the retinal chromatic adaptation. To see whether this interpretation is correct we repeated a similar experiment as the experiment 1, but with the test room decorated chromatically differently, green and red. Fig. 4 shows the room, the green room on the left and the red room on the right seen through W4. Two dotted squares in each picture indicate W1 and W3. The objects in the green room

Fig. 4 Two arrangements of test room: left, green interior; right, red interior.

were real green plants at the left and right sides and a green cloth at the right side. There were a red and a yellow wooden block. The back wall was white and a wooden holder for the test patch was brown. The area percentage of the greenish objects excluding the test patch was 68 % in W3 and 70 % in W4. The objects in the red room were two artificial red roses at the left, real red flowers at the upper left and the lower right, a red cloth at the right, a red box at the left bottom and a pale pink board against the left back wall. There were a green and a yellow wooden block. The area percentage of the reddish objects was 53 % in W3 and 70 % in W4.

5. RESULTS OF EXPERIMENT 2

The sudden change of color appearance of the test patch when the window was changed from W1 to W3 was confirmed. The main interest of the present experiment was to see whether the color appearance was mainly determined by the adaptation to illumination and not by the retinal color distribution. To see that point the color appearance of the test patches at W4 is plotted in Fig. 5 for the cases of yellow and blue illumination of the subject room. Symbols for the test patch are same as in Fig.

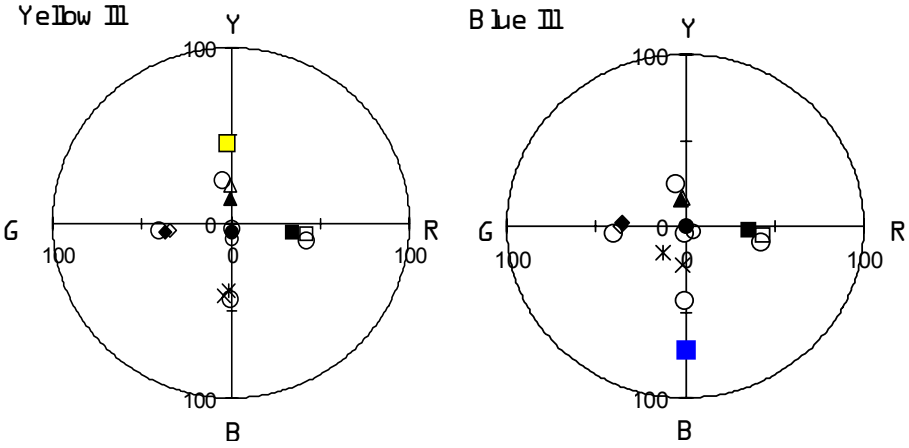

Fig. 5 Color appearance with the window W4 shown by filled signs in the red interior and by open signs in the green interior. Left, yellow illumination of the subject room; right, blue illumination.

4, but filled signs for the red background and open signs for the green background. A large square in each figure indicates the color of illumination and large open circles the original color appearance of five test patches. Two points, open and filled, of each test patch came quite close and often overlapped with each other in the figure. With W4 it was the recognition of the test room and consequently its illumination that determined the color appearance of the test patch and not the color of objects surrounding the test patch.

Recently some researchers investigated color perception by using a real 3D space rather than a 2D display and obtained relevant results to ours. For example, Kraft et al.[5)] investigated the effect of complexity in the scene on the color constancy. Cataliotti and Bonato[6)] investigated the effect of complexity of an inducing field on the appearance of a test patch. Their results can be interpreted how soundly the RVSI is constructed by the initial visual information. We hope that more researchers will do the experiment on the color appearance by using setups of real space, not of a 2D plane.

References

1. Y. Mizokami, M. Ikeda and H. Shinoda, “Color property of the recognized visual space of illumination constructed by interior color as the initial visual information,” Opt. Rev. 7, 358-363(2000).
2. R. Yamauchi, M. Ikeda and H. Shinoda, “Walls surrounding a space work more efficiently construct a recognized visual space of illumination than do scattered objects,” Opt. Rev. 10, 166-173(2003).
3. M. Ikeda, A. Kusumi and H. Shinoda, “Color appearance seen through a colored filter of various sizes,” Opt. Rev. 8, 480-486(2001).
4. M. Ikeda, "Color appearance explained, predicted and confirmed by the concept of recognized visual space of illumination," Opt. Rev. 11, 217-225 (2004).
5. J. M. Kraft, S. I. Maloney and D. H. Brainard, Surface-illuminant ambiguity and color constancy: Effects of scene complexity and depth cues, Perception 31, 247-263(2002).
6. J. Cataliotti and F. Bonato, Spatial and temporal lightness anchoring, Visual Cognition 10, 621-635(2003).