Impressionism, Ukiyo-e and Color Imaging

-A fMRI Study of Color Related Visual Cortex: V4 -

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Abstract

Color imaging is produced from Neo-Impressionism that is the pictures of George Seurat and Paul Signac 19th Century French painting.

These pictures are composed by many color dots, and modern color imaging is constructed of red, green and blue color pixels on a color display. This color imaging system is only one of some systems of the seeing world in our brain. We suggest that there are various seeing color systems from our retina to our brain.

Post Impressionists painted their pictures with various methods and experimented to represent the color world in the brain. Impressionism was greatly influenced by Japanese Ukiyo-e art and artists like Hokusai and Hiroshige. This is called Japonism, the influence of Japanese art on European art, especially impressionism.

Ukiyo-e is a kind of multicolored wood-block print of the Edo period (1603 - 1867). At first, there were just one color wood-block prints with brush-added color in the 1710s, then two or three color wood-block prints evolved in the 1740s, and finally in the 1760s the multi-color wood-block prints called "nishiki-e" were invented.

Ukiyo-e's style differs from European traditional arts and predates Impressionism. It involves drawing the outline of objects and one color painting. The print is composed of the multi-colored plane surfaces. The research of modern scientists has thrown new light on the subject of the difference of picture styles by seeing directly our brain activity using functional magnetic resonance imaging system.

We created some pictures inspired by the pictures of Post Impressionists and Ukiyo-e for functional magnetic resonance imaging to test multiple color-sensitive areas in human ventral occipitotemporal cortex. The results showed that area V4 is activated by the stimulus of reading shapes from its color but not by the stimulus of seeing a colour dot.

We suggest V4 is activated by figures composed of colour dots with geometric pattern, and V4 has low response to the camouflage figure in which colour dots do not include object shapes.

Introduction

Color imaging of current printing techniques and displays are obviously based on the theory of neo-impressionism by Paul Signac and Georges Seurat, and pointillism.

However, color imaging which is a collection of pixel dots is essentially different from pre-impressionism paintings that are drawn by following the contours of the object. The task of drawing color images is different from arranging colors one-dimensionally.

The composition of colors in 2 dimensions requires a totally different logical explanation from looking at single colors in a small vision, such as contrast and assimilation of colors in figures and the background, or categorization of similar colors.

In 1885 and in 1888, Charles Henry, a French psychologist, first proposed that “les lignes”, “les couleurs”, and “les couleurs sombres” each have their own role as basic components in a picture, and that these roles are different from roles expressing the object. Seurat, and later Signac were very impressed by this idea. They drew by dividing the image plane with color dots. Bauhaus also inherited this idea, and for the first time, pure abstract painting was born. Artists like Mondrian, drew pure abstract paintings by constructing the plane with lines and colors, not representing any particular subject. The energetic creation by these “modern artistic revolution” painters during the 1910s and 1920s viscerally expressed this localization of colors and shapes in the visual cortex before neuro-psychologists discovered them.

In 1960s, Hubel and Wiesel found that neurons in cats’ brain react selectively to a transverse line in the visual field, which involves orientation in particular. Livingstone et al. showed the reaction of a particular region towards shape, color and movement in the visual cortex of the monkey brain.

In the 1990s, people were finally able to study the human brain non-invasively. Study on V4 was conducted in 1989 by Lueck et al. and in 1991 by Zeki et al. using PET. In 1995 this was followed by another study by Sakai and in 1997 by McKeefry using fMRI. A study using picture stimuli was conducted in 1998 by Zeki and

Martini, indicating that the more definite objects colored with natural colors would activate more anterior region, V4a. With these study backgrounds our group have also succeeded in projecting V4 activity using fMRI and picture stimuli starting from winter 1999.

Methods

This study was conducted to investigate;

1. Whether V4 is activated when there is a color configuration, a certain size of block of color dots with any sort of shape (like Ukiyo-e style)
2. or whether V4 is activated when color dots resemble the color shape of some object (like Neo-Impressionism)
3. or V4 acts in either case

In regards to the problems of color painting pictures, this is to investigate the conditions necessary for shapes to be read from the colors, and what kind of pathway is taken in the assimilation and completion of colors and shapes.

Visual Stimulation

Fig.1 mono: Gray broken dots, resting stimulus
Fig.2 rand: 4 colored random dot stimulus
Fig.3 kumo: 4 colored cloud shaped pattern stimulus
Fig.4 uzuu: 4 colored spiral shaped pattern stimulus
Fig.5 rect: 4 colored square arrangement stimulus

These stimuli are all 240 X 300 pixels, total 72,000 pixels. 4 colors used in Fig.2 to Fig.4 are the same colors used in the last study, the characteristic 4 colors (JGT, COT, CRO, BG) that constitutes the Ishihara test (refer to reference [9] and [12] for the chromaticity of these colors).

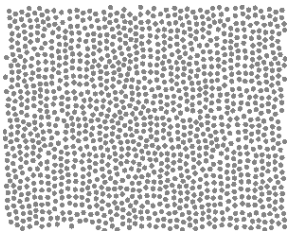

Figure 1. mono

The combination of JGT and COT, CRO and BG are positioned along the pseudoisochromatic line. All colored dots (JGT, COT, CRO, BG) have the same area of exactly 7335 pixels. Each color consists of 10.19% overall, and the color white takes up 42,660 pixels, 59.25% overall. Projector colors were colorimetrized, adjusted using approximate expression so that each color possess precisely equal brightness with mono, the gray stimulus. (note: fig.2 to fig.5 are shown with brightness difference due to monochrome printing) fMRI determines the active region of the brain by taking the changes in magnetic resonance signal, which accompany the change in local blood flow, between the signal at resting state and when performing a task. Imaging is done sequentially from the top and thus it is difficult to time the scanning of the target region. Figure 6 indicates the scan location and the timing in seconds when scanned from the top by TR5000.

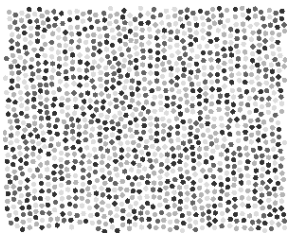

Figure 2. rand

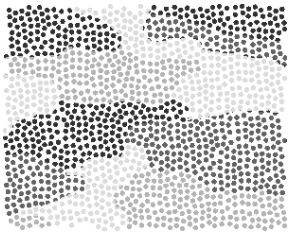

Figure 3. kumo

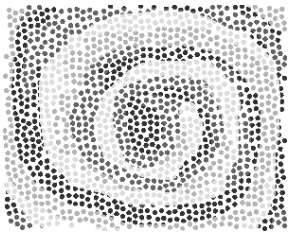

Figure 4. uzuu

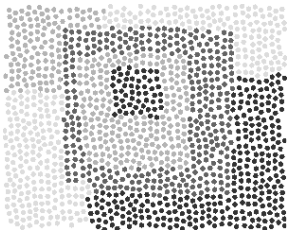

Figure 5. rect

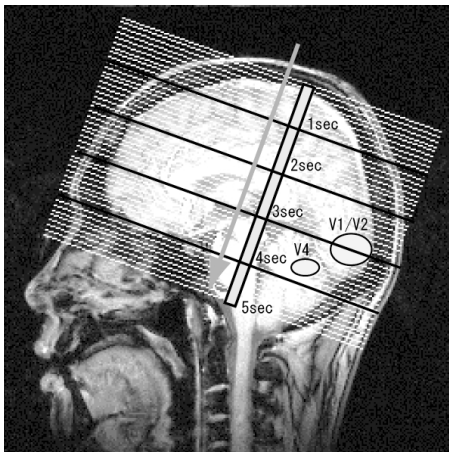

Figure 6. Stimulus presentation and scan timing.

This figure indicates that 3 to 4 seconds after scanning starts should be the target time to image the V1/V2 and V4.

Also, after stimulation, it is known to take 5 to 6 seconds for the change in blood flow to occur. The scan has to be triggered in consideration of the above, and it was decided to present each stimuli for 1 second, after 2 seconds scanning begins, after 3 seconds (after 6 seconds from the beginning) the target region is imaged (fig7). Each trail takes 40 seconds with 8 scans, and 15 trials were conducted providing total of 120 sets of fMRI images in 600 seconds (10 min) experiment time. Task condition (rand, kumo, uzuu, rect) and resting condition (mono) were analyzed with Image calculator ** and SPM99.

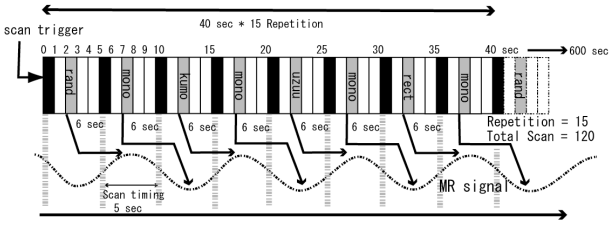

Figure 7. scan timing

Hypothesis

From the previous Ishihara test experiment and the pilot study conducted in July, it was assumed that V4 will not act in rect-mono difference, but would act in ret-mono difference. The problem is the uzuu-mono and kumo-mono difference. If V4 activates with kumo, color configuration is thought to be the important factor and for uzuu, the shape.

Result

By analyzing the active part activated by the difference between task condition and resting condition using Image-calculator, V4 activity at a significant level 0.0001 was detected. Also, analysis with SPM has clearly separated the activities of V1 and V4 (fig.8)

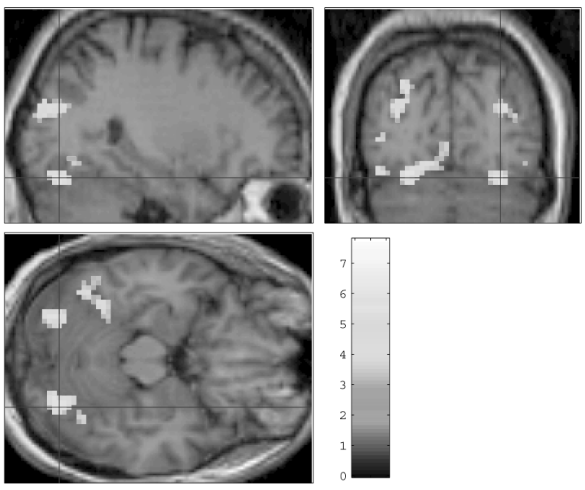

Figure 8. SPM data

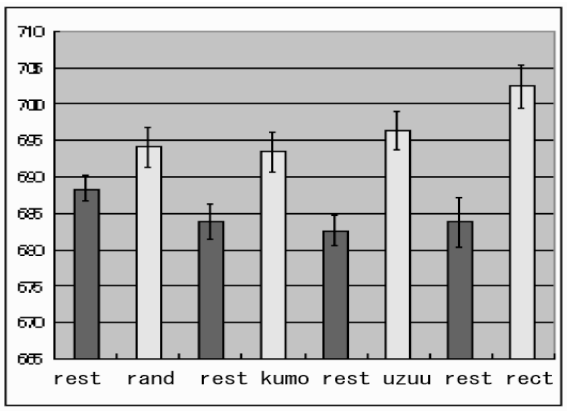

Figure 9

Figure 9 exhibits the increase of the signal compared to mono at V4 region.

The degree of increase is represented by the degree of image density. V4 activity in rand-mono was small and kumo-mono was also as small. The greatest activity was observed in rect-mono as assumed, and uzuu-mono's activity was as large as rect-mono.

Discussion

The result of kumo being close to that of random dot stimulus was surprising because kumo has a high proportion of adjacent dots being the same color. This result suggests that the V4 may be activated by color configuration, the block of color dot of certain size. The activity of uzuu as active as rect was also unexpected. What may be the picture similarity of uzuu and rect?

First of all, when these two stimuli are observed as pictures, they both have a center. A structure that makes you think "something" is there seems important in this case. Kumo and rand's similarity is that these two do not have a geometrical figure to be its center and is a decorative pattern. Kumo seems fluffy as its name "cloud" suggests, and rand is random dot, a texture not resembling any particular object.

Currently, some scientists believe that visual information is processed in parallel in 2 modules in the brain.[19] It is assumed that visual working memory assimilates the information from 2 visual information processing streams, the dorsal stream (processing space, position and motion information) that runs from V1 through the posterior parietal, and the ventral stream (color, shape, face information processing) running from V1 through the inferior part of the temporal lobe, in the confines of the prefrontal cortex.

V4 is located in the ventral stream (color, shape, face information processing). From these data, it is assumed that all of these visual information are inputted in V1 but the texture information may be omitted in V4. In kumo or rand, the same colors and areas of each color were present but they do not possess the "figure" to be its geographical figure or object. V4 does not activate solely from colored dots. Our results indicate that V4 may activate when the construction of dots suggest object characteristics ("what" information processing) Also, it is

assumed that color/shape attribution and texture attribution is separated in V4 or V1/2.

Conclusion

The human color cognition system is not a single mechanism. The fact that there exist stimuli that may or may not activate V4 indicates that the difference between "recognition of color (V1 activity)" and "comprehension of color (V4 activity within the process of cognition of colors as an object)" Random dot stimulus or kumo exhibits low V4 activity even though the same colors and the same amount of color are used as uzuu or rect.

These stimuli have camouflage characteristics to blend into the background and may go through the dorsal stream as texture. As a leopard with its characteristic pattern can blend into a leaf shade background, texture stimuli may activate the motor area when in motion.

Acknowledgement

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**Image-calculator is a analytical program developed by Dr. Atsushi Kandatsu, the Jikei University.

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References

1. D. Mckeefry and S. Zeki, The position and topography of the human colour centre as revealed by functional magnetic resonance imaging. Brain 1997; 120:2229-42
2. S. Zeki & Ludovica Martini:Three cortical stages of colour processing in the human brain. Brain 121:p.1669-1685,19981 Lueck CJ, Zeki S, et al.:The color centre in the cerebral cortex of man, Nature 340:386-9,1989
3. Zeki S, et al.:A direct demonstration of functional specialization in human visual cortex, J Neroscience 11:641-649,1991
4. Sakai K, et al.:Functional mapping of the human colour centre with echoplanar magnetic resonance imaging, Pro Roy Soc Lond B Biol Sci 261:89-98 1995
5. A.Bartels & S.Zeki:The architecture of the colour centre in the human visual brain, European Journal of Neuroscience, vol.12, pp.172-193,2000.
6. MS Beauchamp, JV Haxvy, JE Jennings, EA DeYoe: An fMRI version of the farnsworth-Munsell 100-hue test reveals multiple color-sensitive areas in human ventral occipitotemporal cortex. Cerebral Cortex 9: 257-263, 1999
7. Michael S. Beauchamp, James V. Haxby, Allyson C. Rosen, Edgar A. DeYoe :A functional MRI case study of acquired cerebral Dyschromatopsia, Neuropsychologia 38 (2000) 1170-1179
8. Zeki:The visual image in mind and brain,Scientific American, September, 1992
9. Ichihara, Y.G. : What do you see in a digital color dot picture such as the Ishihara pseudoisochromatic plates? - Web Accessibility palette (WAP)-,Internet Imaging II Proceeding of SPIE, Vol. 4311, pp. 419-426, 2001
10. Kunihiro Asakawa, Satoshi Nakadomari, Yasuyo Ichihara, Atsushi Kandatu, Hiroaki Takeuchi, Satoru Miyauchi, Jun Okamoto, Kenji Kitahara: The ventral cortical activities in occipito- temporal lobe associated with continuous pictorial stimulation, Journal of Kanagawa Rehabilitation Hospital, pp. 1-8, 2000
12. Ichihara YG,Nakadomari S,Takeuchi H,Satoru Miyauchi S,Kitahara K, The difference between seeing a random colour dot picture and reading shapes from the same colour dot picture in the Ishihara pseudoisochromatic plates - Artistic
11. Brazis PW, Graff-Radford NR, Newman NJ, Lee AG. Ishihara color plates as a test for simultanagnosia. Am J Ophthalmol 1998; 126 (6) : 850-1.
12. Hadjikhami N, Liu AK, Dale AM, Cavanagh P, Tootell RBH(1998) Retinotopy and color sensitivity in human visual cortical area V8. Nature Neuroscience 1:235-241 research of coloured picture using functional MRI-AIC2001 Rochester Proceeding 2001 (now printing)
14. Charles Henry, Introduction a une esthetique scientifique, 1885
15. Charles Henry, Cercle chromatique, Ch. Verdin ed., 1888
16. Hubel, D. H. and Wiesel, T. N., (1962) Receptive fields. Binocular interaction and functional architecture in the cat's visual cortex. J. Physiol. 160:106-154.
17. Livingstone, M. S. & Hubel, D. H. (1984). Anatomy and physiology of a color system in the primate visual cortex. J.Neurosci. 4, 309-356.
18. Hubel DH and Livingstone MS (1987) Segregation of form, color and stereopsis in primate area 18. J. Neurosci. 7:3378-3415.
19. Wilson F, S Scalaidhe, P Goldman-Rakic 1993 Dissociation of object and spatial processing domains in primate prefrontal cortex Science 260:1955-1958
20. Post,D.L. & Calhoun,C.S, An Evaluation of Methods for Producing Desired Colors on CRT Monitors. Color Research and Application, 14, 172-186, 1989.

Biography

Yasuyo G. ICHIHARA has been associate professor of the Dept. of Arts and Design of Hosen Gakuen College at Tokyo since 1997. She obtained her PhD from Tokyo National University of Fine Arts and Music in 1991. Her research of Digital Color Palette on the Internet Imaging (1998-2000) is supported by Japan Ministry of Education Sports, and Culture, the grant-in-aid for encouragement of young scientists. She joined at the Internet Imaging program committee at EI2000 on the advice of Giordano Beretta.