Capturing "colors"

Development of a neural circuit producing colors

Yoichi Sugita Cognitive and Behavioral Sciences Group of Neuroscience Research Institute

Neural mechanism to capture "colors"

Even if wavelength components of light radiation vary largely, humans are able to recognize objects' colors correctly. Assume that we illuminate the diagram shown on Fig. 1 from three sources of light only (S: short wavelength, M: middle wavelength, and L: long wavelength). Rectangle A looks green and is located at the center of the diagram on Fig. 1A. It is reflecting light by each of the three sources of 1, 4.5, and 4 (units), respectively. On the other hand, rectangle B appears yellow of 1, 5, and 9 (units), respectively. Now presume that we change the intensity of the light sources so that green rectangle A reflects respectively 1, 5, and 9 (units). Therefore, the light entering our eyes should be the same as the reflected light at the yellow rectangle B. Notwithstanding, this rectangle B still looks green: it never appears as yellow.

Thus even if the characteristics of light coming into our eyes change to a great degree, we retain "color consistency," by which we can recognize the color of an object correctly. That fact indicates that the light itself that

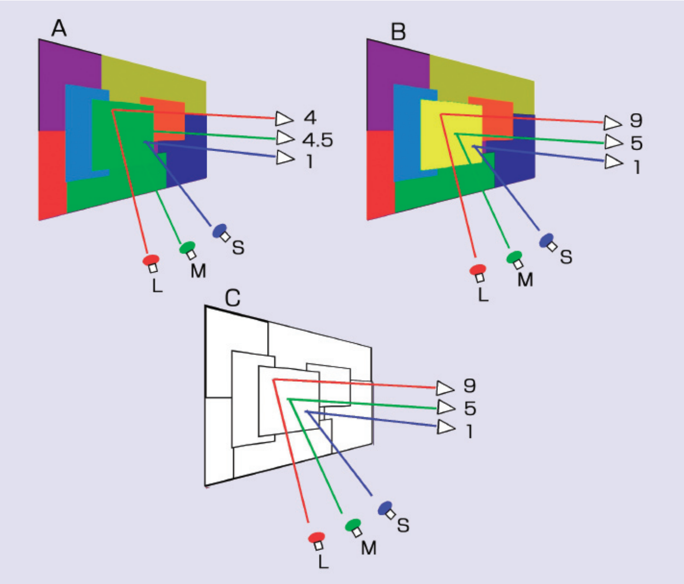

Figure 1: Color consistency
Squares of green (A) and yellow (B) embedded in a Mondrian figure (geometrical abstract figure). We illuminate this form of the figure using lights from three sources, each of which is having a different wavelength. The green square reflects the light of short wavelength S, middle wavelength M, and long wavelength L respectively by 1, 4.5, and 4 (units), while the square B appears yellow by respective illumination of 1, 5, and 9 (units). We next adjust to intensify the middle wavelength light by slightly more, and long wavelength light by more than double so that the reflective light from the green square A becomes equal to that from the yellow square. Then would the square A appear as yellow?

Seeing "taste" in the brain

Professor **Takashi Yamamoto**
Graduate School of Human Science Research at Osaka University

The research in which food tasting is understood as part of brain function is underway. As a simple experiment, we tend to use sweet and good-tasting sugar solution or bitter and bad-tasting quinine solution. In the primary gustatory area (the area from the frontal operculum to insula), which recognizes taste, every different part is activated depending on the quality of the taste given. The amygdala and the anterior orbitofrontal cortex become strongly activated when a person tastes something delicious, the posterior orbitofrontal cortex and the anterior cingulate gyrus get strongly activated when a person tastes something bad-tasting.

Odor also plays an important role in taste. The combination of odors and tastes for every food image is determined based on each person's eating experience. In the experiment we have, we first have the examinee smell a food odor such as that of a banana. Next, we show an image of a banana or strawberry, for example. Subsequently, we take a measurement using MEG. Activities at the occipital lobe and the temporal lobe become intensified if the banana image is combined with an actual banana odor, or if the strawberry image is supported with an actual strawberry odor – in other words, if anything expected appears (see Figure).

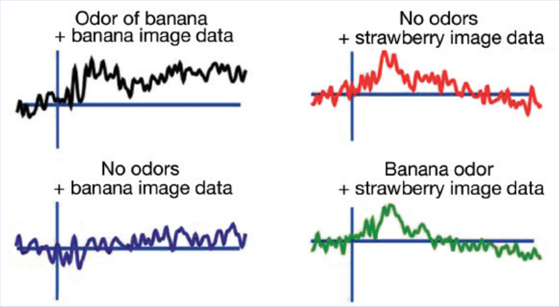

Figure: MEG responding waveform taken from the back of the head.
Cumulative data of 100 times obtained from the same examinee (20-year-old female). The analysis time period is 200 ms before and 1000 ms after the image was presented, as shown by the longitudinal lines.

Consequently, when you smell a good odor first, see the food next, and put it in your mouth to taste to feel good, the various parts of your brain become activated. Once the cerebral mechanism becomes better clarified in terms of identification of taste quality, and emotion of good tasting or bad tasting, the true objective evaluation on tasting would be put into effect so that it would be expected to help apply it for development of much better tasting food.

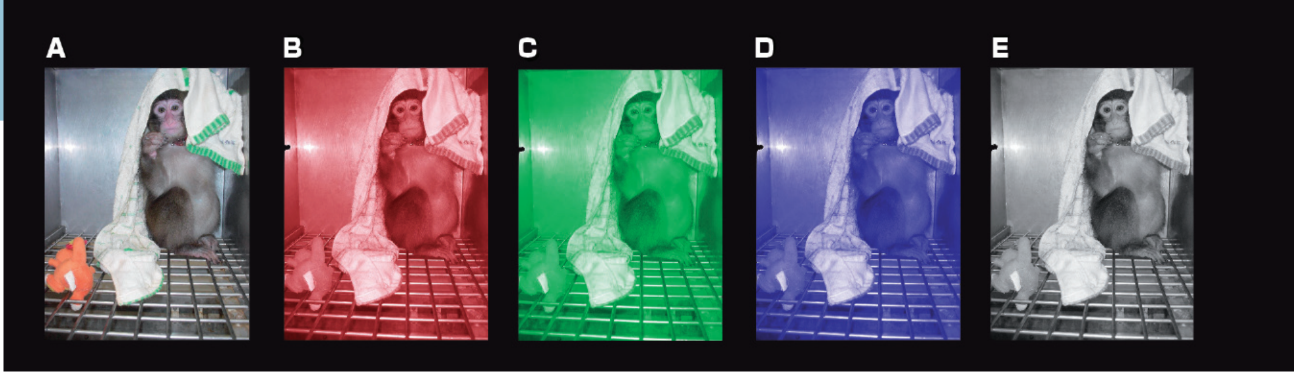

Figure 2: Imaging photograph of monochromatic illumination
(A): The photo under the normal illumination (A). Imaging photo of illumination with (B): Long wavelength (red), (C): Middle wavelength (green), and (D): Short wavelength (blue). If illuminated with monochromatic light, none of the colors of the monkey, the red necklace worn, and the picture on the towel, or the color of the doll would be recognized, just as if you were looking at a black-and-white picture (E).

comes into our eyes does not include "color" information. The "color" of an object can be identified without much difference, even if the wavelength components of the light that comes into our eyes change to a great extent, because the "color" is created when the color information passes in the chain of neural link from the eye's retina to reach the cerebral cortex. The neural function to produce "colors" (the sense of color) has been conceptualized as genetically provided in humans, but the actual structure and function of the neural circuit network are not yet clarified.

Experiment on monkeys' "sense of color"

We raised a monkey from birth until it became one year old, allowing it only the monochromatic illumination that we provided so that it was unable to recognize any color. During that time, however, we changed the wavelength of the monochromatic light to red, green and blue alternately every minute, so that all three kinds of color acceptance cells (visual cortex) in the retina became active. Then we examined the monkey's sense of color. We found that it had difficulty in discerning color similarity and color consistency. After we trained it for a long time to make it capable of choosing the right object of the same color as that of a sample, the monkey finally achieved the same level of ability of normal monkeys. However, for color similarity testing, in which it was required to choose a nearly similar color to the sample one, he had a totally different score from what the other normal monkeys did.

This result tells us that the monkey raised only in a monochromatic light classifies colors differently from other normal monkeys. Furthermore, the result of the test in which the monkey selected one color out of several different colors varied to a great extent by every condition in which the illumination was given. The monkey raised only with a monochromatic light was not provided with any "color consistency."

These results all mean that the "sense of color" is not something that is genetically given, but can be given through experience. By more fully examining the neural activities of the monkey with the color-sensing problem, we expect to clarify more of the structure and the function of the neural circuit network, which are the bases of "color consistency."

Competition between the bottom-up and the top-down flows

Professor **Takao Sato**
Graduate School of Humanities and Sociology at University of Tokyo

When you think about the mechanism of human vision, i.e., "how we perceive objects and the environment," you might think that the information received by the eyes is processed sequentially through various stages. However, our vision is not accomplished by such a sequential flow alone. Various pieces of knowledge and assumptions about objects in the external environment and the environment itself are stored in the higher parts of the brain that reside beyond the primary visual cortex, which is responsible for early visual information processing. When an object is seen, the bottom-up information coming up from the eyes to the brain, and the top-down information that comes down from the database reside in the higher levels of the brain, meet, compete, and compromise with each other in one way or another. Only after such a compromise, an object can be perceived and understood.

For example, when you look at the inside of a mask with two eyes, it looks concave. However, when you look at it with only one eye, you see it concave at first, but if you keep looking, it eventually starts to appear convex. The depth information (binocular stereopsis

information), which functions when looking with two eyes, does not function with only one eye and the depth information becomes ambiguous. In such occasions, the top-down information, that "face are convex" becomes predominant, and you perceive the inside of the mask convex although it is actually concave.

I am trying to understand the mechanism of the visual perception through psychological experiments. However, to explore the nature of such a complex mechanism, it is important to interact with researchers from various research fields such as neuro-physiologists who study brain mechanism, researchers in brain imaging, modeling people who study theory, and experts in computer vision who attempt to build artificial vision systems.