Neural coding of color.

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Abstract

We measured multi-channel MEG responses to a set of color stimuli (for twelve colors). Subjects are just gazing at colored squares during the measurements. Each current dipole in the brain, thus localized response to the corresponding color stimulus, is moving inside area V4a (Bartels & Zeki, 2000) showing a characteristic orbital path. In our measurements, such absolute-positional errors are still large. However, the orbits of estimated current dipoles are localized in quite a small volume. This localized volume corresponds to V4a. Current dipoles are forming different orbits from each other. On the other hand, the coarse-grained overall orbit observed within 1-cubic-mm V4a conserves topological relation in the chromatic coordinate. Our results suggest that the neural coding of chromaticity topologically corresponds to well known geometrical coding of chromaticity. Therefore the observations could be interpreted as that the chromatic topology is spatially represented and that the refined coding of a color is spatiotemporally represented in V4a.

Introduction

We all have almost complete understanding for the coding in color system going through with a long-term accumulation of intensive research. A color is represented by a vectorial quantity. Color system is depicted in an elegant three-dimensional coordinate system. Using the color system, we can quantitatively observe/represent/specify a color. In spite of this successful pursuit, we have never been able to obtain the knowledge how the color perception is coded in the brain, thus the neural coding of color perception. We measured multi-channel MEG responses to a set of color stimuli (for twelve colors). Generally speaking, the error to the absolute position of the local activity, which is calculated as the solution to the inverse problem, is large in a MEG measurement. However, the relative positions to one another provide quite detail information of the responses. We investigate the coding of color and the color system with refined MEG observations.

Methods:

1). MEG responses were measured during color presentation tasks, using whole-head type 160ch MEG system in KIT. (experiment 2) (fig.1)
2). Twelve Color stimuli (3.5 [deg] x 3.5 [deg] square) were presented at the center in the left-upper quarter. (fig.2)
3). The luminance of all twelve colors are calibrated to a sensation-equated luminance by a drifting-grating (fig.3) experiments (experiment 1). (Takeuchi et al., 2003)
4). The colors of stimuli were chosen from the topologically circular path on the chromatic plane (fig.4) based on experiment 1. These colors were presented sequentially and/or randomly along the chromatic circle, while each presentation lasts 300 [msec].

Fig. 1. Whole-head type 160ch-MEG

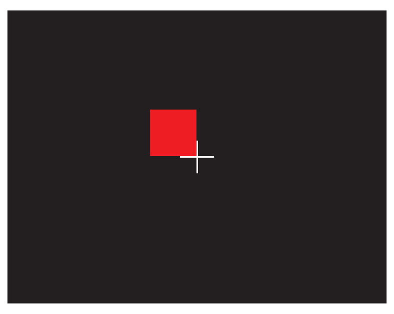

Fig. 2. A snapshot of a stimulus sequence for color presentation tasks. (experiment 2)

Fig. 3. Stimulus for experiment 1.

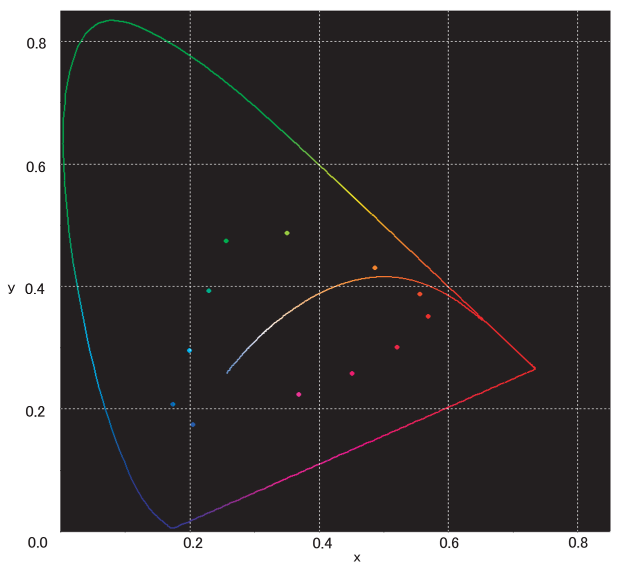

Fig. 4. Chosen colors for stimuli in experiment 2.

Analysis:

1). 160ch data were treated by non-parametric ICA in both the time and frequency domain.
2). Only a few independent components were obtained within the visual cortex.
3). The independent components were combined into a temporal component. Estimated current dipoles were plotted with MRI sections.

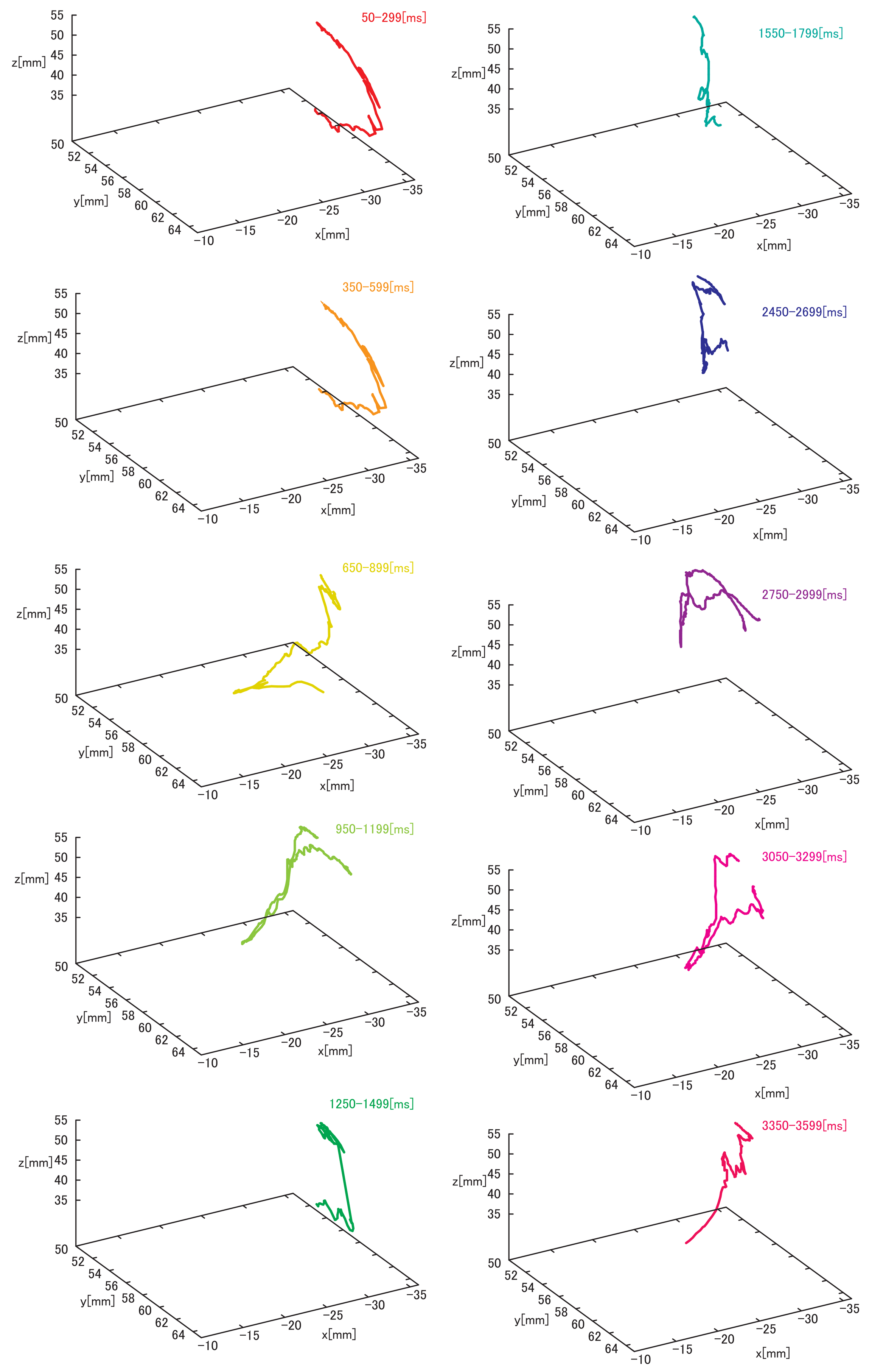

Fig. 7. Orbits of current dipoles within V4a for each color. Orbits are colored by the corresponding color to the respective stimuli (Note: Those are lying within a 1-cubic-mm volume.)

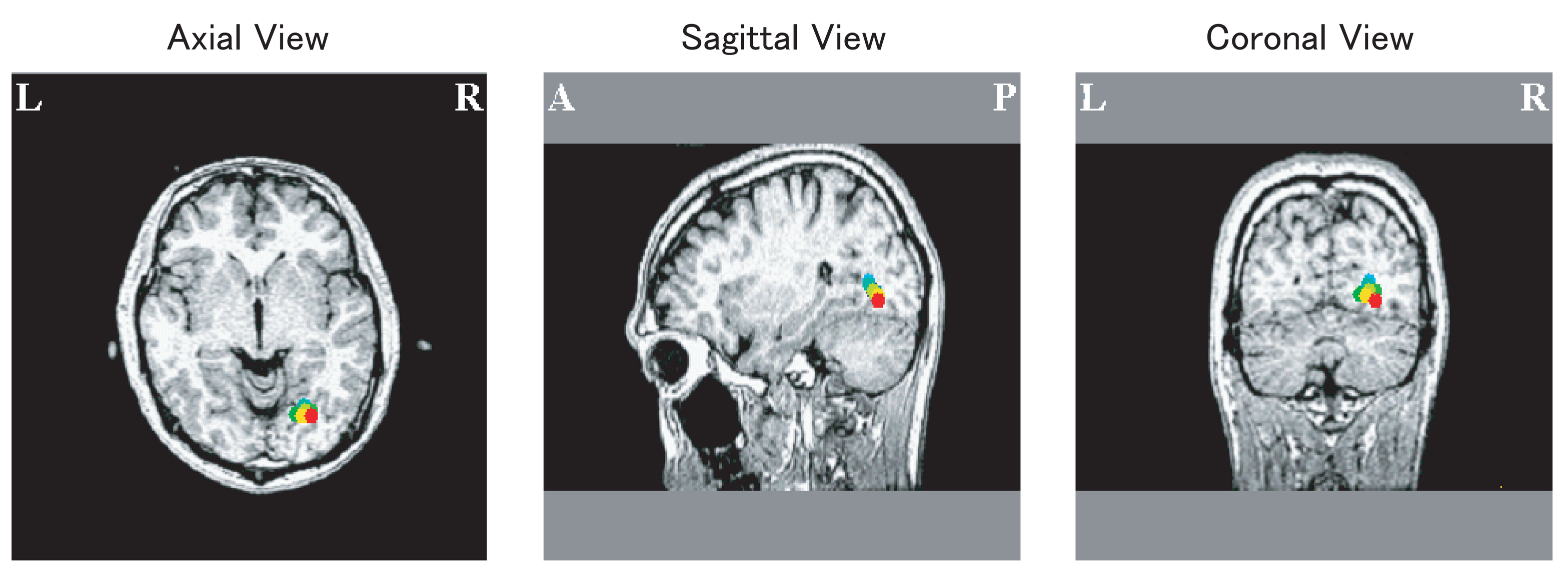

Fig. 5. The absolute position of the current dipoles.

Results of experiment 2:

Fig.5 shows the absolute position of a current dipole estimated by combined independent components within the visual cortex.
Fig.6 shows the orbit of a current dipole according as the presented twelve colors are changing along the path in the chromatic plane (fig.4).
Fig.7 shows the refined orbits for each color stimulus.

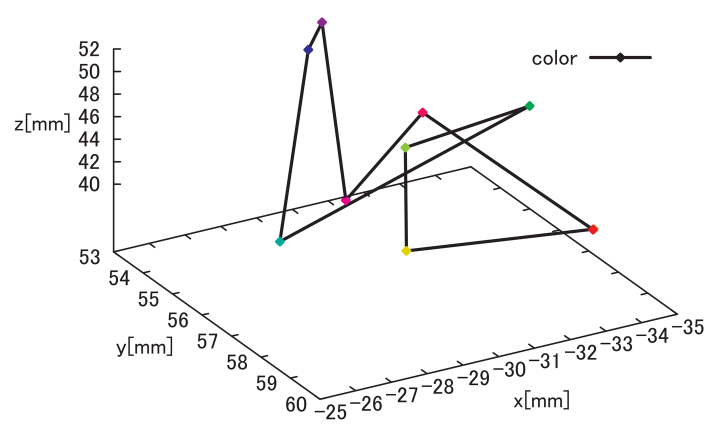

Fig. 6. Overall chromatic orbit of current dipole within V4a responding to color sequence.

Conclusion:

The neural coding of a color is represented by a spatiotemporal activity in V4a. (Spatiotemporal Representation)
Chromatic topology is conserved in the coarse-grained current-dipole orbit. (Spatial Representation)

Reference:
1. Bartels, A. & Zeki, S. (2000) "The architecture of the color centre in the human visual brain: new results and a review" European Journal of Neuroscience 12, 172-193.
2. Takeuchi, T., De Valois, K., K. & Hardy, J., L. (2003) "The influence of color on the perception of luminance motion." Vision Research 43, 1159-1175.