A critique of a proposed three stage cortical process for color recognition in the human brain

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Based on the experimental evidence, Zeki and Marini suggest that cells in the inferior temporal cortex encode the relationship of color to object. This interpretation is contrary to recent studies in computation that propose that cells in the inferior temporal cortex explicitly encode specific color. It would seem, however, that this relationship interpretation is supported by the move away from phrenological views of the brain within neurology.

Their suggested three stages of color processing are:

1. *Registering the color of every point on the visual field.*
2. *Comparison of the color of light from one area with that of surrounding area.*
3. *Relating abstract colors to objects and surfaces in the visual field.*

The first two stages are concerned with color in the abstract sense; there is no involvement of object recognition. Stage one occurs in V1 and V2, while stage two is mostly contained within V4. The placement of these preliminary stages is backed up sufficiently by previous experiments. Stage three, which is proposed in this paper as different from previous interpretations for the activation of cortical areas beyond V4 in color processing, occurs mostly in the inferior temporal cortex and hippocampus.

In the end, Zeki and Marini conclude that both the views of Helmholtz, who in 1867 claimed that color vision was “due to an act of judgement, not an act of sensation”, and Hering, who in 1877 claimed that “all objects that are already known to us from experience, or that we regard as familiar by their color, we see through the spectacles of memory color, and on that account quite differently from the way we would otherwise see them”, are vindicated by the

results of the study. Automatic color computation in the abstract is always performed (stages 1 & 2), and memory and learning are invoked when color is part of an object (stage 3).

Zeki and Marini are cautious not to jump to any conclusions regarding the actual involvement of memory and learning in concrete object color recognition, and rightly so. Their experiments do not point to any causal direction of the relationship between object and color in their third stage of color processing; their experiments merely reveal co-activation of the memory and learning centers of the brain when color within objects is processed. The differential activation of brain areas when a subject is presented with normally versus abnormally colored objects should be further studied.

Indeed, an interpretation of the co-activation of the cortex and hippocampus may be that for normally colored object, which are those we have likely come in contact with already and that have *normal* colors found in the natural world, the activation of such cortical areas signifies a proper match between what our visual system sees and what our memory system knows. In effect, there is a proper match, and we recognize the object that we see.

When presented with abnormally colored stimuli, which have familiar and normal shapes, there is a mismatch between the visual stimulus and our knowledge of objects in the world. We have likely never come in contact with such objects colored in such a way, and further the colors aren't natural—they don't occur in nature, and are therefore not associated with natural objects. Our learning mechanism (which involves areas of the hippocampus) must be invoked, so that we can learn this novel stimulus. The disparity between the memory match for the normally colored object and mismatch for the abnormally colored object, as well as our learning process for novel stimuli accounts for the different activation when viewing the different stimuli.

Zeki, S. and Marini L., (1998). Three cortical stages of colour processing in the human brain. *Brain*, 121, 1669-1685.