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New study reveals insight into how the brain processes shape and color

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A child's face, the upper portion of the photograph is in black-and-white and the lower portion is in color. The image graphically represents the essential findings of the paper, which show that the face-processing system has a strong achromatic luminance bias, while color processing is handled by discrete zones of object cortex adjacent, and yoked, to face patches. The orientation of the image, with the achromatic portion on the top and the colored portion on the bottom, matches the spatial configuration in inferior temporal cortex of the parallel face-processing and color-processing channels. Credit: Bevil R. Conway, Wellesley College

A new study by Wellesley College neuroscientists is the first to directly compare brain responses to faces and objects with responses to colors. The paper, by Bevil Conway, Wellesley Associate Professor of Neuroscience, and Rosa Lafer-Sousa, a 2009 Wellesley graduate currently studying in the Brain and Cognitive Sciences program at MIT, reveals new information about how the brain's inferior temporal cortex processes information.

Located at the base of the brain, the inferior temporal cortex (IT) is a large expanse of tissue that has been shown to be critical for object perception. This region of the brain is commonly divided into posterior, central, and anterior parts, but it remains unclear as to whether these partitions constitute distinct areas. An existing, popular theory is that the parts represent a hierarchical organization of information processing, a notion that has previously been supported by functional magnetic resonance imaging (fMRI) in monkeys. For their study, Conway and Lafer-Sousa used non-invasive fMRI to measure responses across the brains of rhesus monkeys to a range of different stimuli and obtained responses to images of objects, faces, places and colored stripes. "The technique enabled us to determine the spatial distribution of responses across the brain, and has been useful in figuring out how the visual brain is organized," Conway said.

Conway, a visual neuroscientist and artist, examines the way the nervous system processes color using physiological, behavioral, and modeling techniques. Conway and Lafer-Sousa assert that color provides a useful tool for tackling questions about processing in the IT region, as it has little "low-level" feature similarity with shapes (psychological work shows that color can be perceived independent of shape)—therefore any relationship between color-responsive and shape-responsive regions should reflect fundamental organizational principles.

"Shape and color are both properties of objects and are processed by the parts of the brain known to be important for detecting and discriminating objects. However, the way this part of brain is organized has not been clear, for example, is color computed by different parts of this region than those that compute shape?" The answer to this question, Conway said, has deep implications for understanding the general computational principles used by the brain and how the brain evolved.

"Our work showed that, to a large extent, color and faces are handled by separate, parallel streams, and that these pieces of information are processed by connected, serial stages," Conway said. "One can imagine the processing as an assembly line, where some aspect of faces – and some aspect of color – is computed first. The output is then sent to another region downstream that makes a subsequent computation."

They hypothesized that the earliest stages in color processing involve detecting and discriminating hue, while the later stages compute color-memory association. For example, the brain may first compute that yellow is diagnostic of banana, then later, color categories are recognized; for example, limes, grass, and fern leaves are all "green."

"The most striking aspect of the study is what it reveals about the precision of the organization of the brain. We often think that because the brain consists of billions of neurons, that at some level it must be quite variable how the neurons are organized," Conway said. "The study shows that there is a remarkable precision in organization of the neural circuits for high-level vision, which will make tractable many questions bridging cognitive science and systems neuroscience."

As a visual artist, Conway said the aspect of the research he finds most satisfying is the beauty of the organizational patterns that, he said, are "clearly are the result of a set of underlying organizational principles." He continued, "It is interesting to think that the brain reflects what artists have long recognized: that color and shape can be decoupled, each represented somewhat independently—think of color monochromes versus black-and-white line drawings. The neural architecture provides a reason why this is effective or possible."

The researchers note that it remains unclear whether the organizational principles found in humans apply to monkeys, an important issue that bears on cortical evolution. However, their results suggest that the IT comprises parallel, multi-stage processing networks subject to one organizing principle.

The work for the study began in 2008 at Massachusetts General Hospital and Harvard Medical School. The paper, "Parallel, multi-stage processing of colors, faces and shapes in macaque inferior temporal cortex" is available now in the journal *Nature Neuroscience*.

More information: "Parallel, multi-stage processing of colors, faces and shapes in macaque inferior temporal cortex." Rosa Lafer-Sousa. Bevil R Conway. *Nature Neuroscience* 16, 1870–1878 (2013) DOI: 10.1038/nn.3555

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