How Does the Brain Recognize a Face?

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The smile of the Mona Lisa may remain forever ineffable, but at least now science can measure the difference between the real thing and its many imitations.

A team of neuroscientists including Irving Biederman, the holder of the Harold Dornsife Chair in Neurosciences in USC College, say they can predict with near-perfect accuracy whether two faces resemble each other enough to fool a human observer.

Their study provides rare insight into the hard rules guiding one of the most subjective of processes.

The researchers presented their results Nov. 6 in San Diego, at the annual meeting of the Society for Neuroscience.

The study used a face recognition computer model, previously developed by Christoph von der Malsburg of the USC Viterbi School of Engineering and the College, to try to understand how human brains recognize faces.

“We knew that the model could do a good job at matching one image of a face to a different picture of the same person,” Biederman said, “but we did not know whether it was doing it in a manner that mimicked the way people were doing it.

“Our experiments showed that if the model computes two faces to be very similar, then people will have a hard time telling the difference

between the two faces."

The research group, which included lead researcher Xiaomin Yue, a 2007 alumnus of the College's psychology doctoral program who is now a research fellow at Massachusetts General Hospital, interpreted the consistent results as evidence that the computer model faithfully represents neural processes.

"It's quite likely, or at least plausible, that the brain is doing face matching this way," said Biederman, professor of psychology and computer science.

To test the model, the researchers showed a dozen volunteers a triangular array of three faces for a half a second. One of the lower faces was an identical match to the upper face, while the similarity of the nonmatching face, as measured by the model, varied slightly.

Biederman said the model "predicted almost perfectly" which faces would stump the study subjects, leading them to make slow and incorrect decisions.

"All subjects showed exactly the same pattern," he said.

The model builds on previous studies of the first area in the visual cortex to receive signals from the optic nerve. Known as V1, the area contains hundreds of millions of neurons tuned to detect contrast between light and dark.

Each neuron fires only when its simple preferred feature — say a white bar on a black background — appears in a unique location, at a unique angle and at a unique size. This pattern of neuronal firing then drives networks of neurons in later stages that represent faces, objects and scenes.

These later networks allow the brain to recognize objects even if they appear in a different orientation or with a different direction of illumination.

This ability comes at the expense of some of the data acquired by V1, including details useful in facial recognition, Biederman said.

For that task, which demands very fine discrimination, Biederman and others believe that the brain reverts to a V1-type of image analysis, though at a risk of error if the viewing conditions change.

For example, humans find it almost impossible to recognize a face if it is upside down, or lit from an unfamiliar angle, or viewed as a photographic negative. Not so with objects.

Biederman said the study also helps explain why many beginning artists struggle to represent objects believably.

“The hard part about learning to draw is not drawing the object,” Biederman said, meaning that the artist must focus on V1-acquired properties, such as reflectance, orientation and graininess, that the brain automatically subordinates.

Biederman, who has explored aesthetic theory with his research on visual perception, will investigate the conservation of aesthetic principles in ancient cave art and in remote tribes in two upcoming papers.

Source: USC College