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RESEARCH

LETTER PERCEPTION EMERGES FROM UNSUPERVISED DEEP LEARNING AND RECYCLING OF NATURAL IMAGE FEATURES

The use of written symbols is a major achievement of human cultural evolution. However, how we learn to visually recognize letters, which are abstract symbols but can appear in a myriad of font types, styles and sizes, was still an unsolved problem in cognitive science. A study from the University of Padova published in *Nature Human Behaviour*, coordinated by **Professor Marco Zorzi (with Alberto Testolin, University of Padova, and Ivilin Stoianov, National Research Council**) addressed this question by reproducing the human ability to perceive letters in computer simulations based on "deep learning", the last frontier in artificial intelligence. An artificial neural network was first trained on thousands of patches of "natural images" (from pictures of landscapes) so that the network's neurons learned to represent basic visual features (such as oriented edges), as it happens in the primary visual cortex of the brain. Then, the same network "observed" images of letters that varied in font, style and size, without receiving any information about letter identity.

Marco Zorzi

Neurons in the deepest layer of the network developed complex visual representations, up to resembling abstract letter shapes, by combining the simpler visual features coded by the neurons of the preceding layer. This form of learning based on observation and partial "recycling" of pre-existing neuronal circuits is much more similar to human learning mechanisms than the learning algorithms used in recent deep learning applications. The abstract representation emerged in the network made letter recognition efficient, robust to visual noise in the images, and it allowed to accurately simulate psychophysical data on human letter perception. In other words, the deep neural network was found to "see" letters in the same way as human observers.

Finally, the finding that learning about letters is facilitated by reusing natural visual primitives supports the well-known and fascinating hypothesis that the shapes of symbols across all human writing systems has been culturally selected to adapt to the neural mechanism that assembles them from simple strokes.

Testolin, A., Stoianov, I., & Zorzi, M. (2017). Letter perception emerges from unsupervised deep learning and recycling of natural image features. *Nature Human Behaviour*. doi:10.1038/s41562-017-0186-

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