Elements of visual perception

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How do we recognize and remember complex visual objects? Experiments on monkeys by Fujita et al., described on page 343 of this issue, suggest that a moderate-sized collection of almost iconic figures may be the alphabet in which our visual memories are written.

This article has several long studies showing the response properties of neurons in the anterior interlaminar core (IT), the part of the brain necessary for visual object recognition and most closely connected to neural circuits thought to subserve memory. It is in the IT that neurons were discovered long ago to respond selectively to images of complex objects, such as a face or a hand. In several laboratories over the years, images from many trays of slides — of people, of events from holidays on the farm or at the beach — have been shown to monkeys, and each IT cell responded well to different subsets of these stimuli. These findings engendered several interpretations, including the notion of the "grandmother cell" that you are able to recognize your grandmother because somewhere in the IT there is a cell selective for her image. The greatest difficulty with this notion is testing it. Because one could try only a limited array of stimuli, one could never be confident one had found the best stimulus for a cell and never be certain how selective such cells really are.

Tanaka’s laboratory has brought a new twist to the story. Columnar organization of the IT cortex. Columns of cells selective for a range of similar stimuli (for example, the coloured bars) are interspersed among columns unresponsive to those stimuli but selective for other complex visual qualities.

Simplified and abstracted the features necessary for eliciting the strongest responses of single neurons, often improving the response over the best obtained with any complex real object. Their new finding is that these visual patterns organize the IT into repeated arrays of columns. In areas of the brain whose properties we understand relatively well, such as the primary visual cortex, cortical columns organize the most significant features of neural responses. The fact that the iconic stimuli described by Fujita et al. also determine the columnar arrangement of the IT is a powerful testimony to the validity of their characterization of the cells’ receptive fields.

Why should the most important stimuli for an area of cortex organize its columns? One possibility is that perception feeds the combined output signal from a series of neighbouring columns. This approach has led to explanations of a variety of adaptation phenomena (that is, changes in perception following prolonged exposure to one stimulus). It also allows distance in the cortex to be a surrogate for distance in the representational space, and for neural computations that depend on the computational geometry of cortical maps.

Another possible reason is developmental — that neuronal connections are shaped by correlations in activity, and that the most important stimuli, which cause the greatest modulations of activity, come to be the most closely linked. Often, but not invariably, these close synaptic links would take the form of columns, although in other circumstances the same process aggregates cells with similar responses into patches, clumps or laminae instead. Regardless of the reason, the fact is that columns commonly specify the most significant stimulus features.

A column encoding scheme is quite the opposite of that proposed elsewhere for this area of the brain, as well as for the olfactory system. There (outside the pheromone-detecting system at least), each cell’s response has been conceived of as one dimension of a very high-dimensional space in which stimuli are classified by some sort of neural network. It is thus an advantage for the cell responses to be as different from one another as possible, so that the dimensions of the classification space are maximally orthogonal: that is, the more distinct each cell’s response is from the response of any other cell, the more information is carried by that cell. The view that every cell contributes its unique response spectrum to perception makes a virtue of necessity when the experimenter does not discern the simplicity of the properties that organize a brain area. Like the notion of the grandmother cell, it is difficult to test. It will be interesting to see whether our present views of orthogonal representations hold in, for example, the olfactory system, stand the test of time.

If the IT columns function as suggested, the size of the anterior IT and the size and spacing of the IT columns of similar specificity set an upper limit of perhaps a thousand for the number of different "letters" in the visual alphabet. Given the remarkable capacity for perceiving and learning a vast number of new objects, it may be that multiple columns and receptive fields are. Are they dramatically different or do they represent the same visual environments? Does a period of intense experience with particular stimuli make them change even in adults? These are among the next questions that will have to be addressed.

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