are findings that show memory impairments when sharp-wave ripples are blocked\(^{12,13}\). Furthermore, it seems that learning dynamically regulates the drive to generate ripples, as if to ensure that there are enough events to consolidate the newly learned information\(^{14}\). Such increased activation of more ripples, together with shifting the content of ripples toward experiences of interest, may be the ingredients that are required to make memories permanent. Moreover, it is known that long-lasting memories, once established, do not require the hippocampus for their persistence\(^{15}\), and it will therefore be interesting to see whether the dopamine-promoted sharp waves in the hippocampus are responsible for eventually taking themselves out of the loop.

### COMPETING FINANCIAL INTERESTS
The authors declare no competing financial interests.


**Cortical geography is destiny**

Charles E Connor

A study demonstrates that learning different character sets produces a repeatable arrangement of distinct cortical modules, suggesting that a preexisting cortical architecture is repurposed during learning.

The authors designed an ambitious, long-term experiment to leverage the manipulability of developmental learning in monkeys. They trained juvenile monkeys on not just one symbol set, but three: Helvetica alphanumeric characters, Tetris-like block configurations and cartoon faces. For each 26-character set, monkeys learned associated reward values ranging from 0 to 25 drops of liquid. In each behavioral trial, two symbols were presented on a touch screen, and monkeys earned the reward associated with the symbol that they touched. They learned, over the course of 6–8 months for each set, to select the higher value symbol on most trials. Importantly, different monkeys learned the symbol sets in different orders: some started with Helvetica, others with Tetris (Fig. 1a). After learning was complete on all three sets, Srishasam et al.\(^3\) used fMRI to look for brain regions selectively responsive to the learned symbols.

If you had asked me beforehand, I would have predicted the result diagrammed in Figure 1b, a single module sensitive to all three symbol sets. That seems reasonable: once the brain has gone to the trouble of setting up a new system for translating screen symbols into reward values, why not just tweak that system to learn additional symbols? But I would have been wrong; the authors found that the three character sets were represented in three distinct cortical patches.

If you had given me that hint, three distinct patches, and asked me to predict their arrangement, I would have bet on one of the results shown in Figure 1c.d. My first guess would have been that training order determines relative position (Fig. 1c), on the assumption that squeezing new modules into the cortical map is constrained in a particular direction. For example, new modules might be progressively added in the rostral direction, as cortex becomes more plastic as you move forward in the visual hierarchy, further away from primary visual cortex. My second guess would have been a haphazard arrangement (Fig. 1d), as squeezing new modules into the cortical map might be subject to random availability of territory at time of learning and map variability between individuals.

It turns out that none of my reasonable guesses would have been correct. Instead, Srishasam et al.\(^3\) got the surprising result diagrammed in Figure 1e: three distinct modules in inferotemporal cortex (IT), in the same relative locations regardless of training order—faces, Helvetica and then Tetris, from top to bottom (dorsal to ventral). This seems interpretable only under the repurposing hypothesis; there must be some preexisting organization of visual processing characteristics with differential affinities to the three symbol sets. This is more obvious in the case of the cartoon faces, which activated cortex near previously identified face patches\(^4\). It is far from obvious for the Helvetica and Tetris symbol sets, yet the Helvetica and Tetris modules reliably appeared at the same relative locations, regardless of which was learned first. There must be some preexisting visual processing region with greater initial affinity for Helvetica (perhaps because it contains...
of alphabets was constrained by these preexisting cortical specializations. This is a reasonable inference based on indirect evidence, including an apparent competition between letter and face sensitivity in the left hemisphere. But Srihasam et al. have done the controlled experiments in monkeys that substantiate this postulate directly. Their results bear not just on cortical organization, but on learning in general. Some types of learning may be viewed as repurposing preexisting cortical machinery, which would constrain both what can be learned easily and how learning affects previous skills and knowledge.

The most exciting parts of this story are yet to come. Because Srihasam et al. have produced a VWFA-like phenomenon in monkeys, it will be possible to study the detailed changes in neural processing that underlie symbol learning. With microelectrode recording, neural tuning functions in various parts of IT are highly interpretable in terms of contour, surface and medial axis (skeletal) configurations, face feature configurations, and scene information. The new findings reported here by Srihasam et al. argue that these native tuning functions are the raw materials from which symbol modules are fashioned. The ways in which these tuning functions are transformed, on short and long timescales, must be some of the most fundamental mechanisms of learning.

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