Milliseconds matter -

A cortical code based on short delays in synchronized neuronal activity

How does the brain represent visual information? Two major aspects of neuronal activity can alter in response to a stimulus: The number of action potentials that is generated (*firing rate*) and the relative time at which they occur. In the retina, both the number and the timing of action potentials (*spikes*) precisely reflect stimulus properties. In the cortex, neuronal responses are more variable. Thus, it has been argued that in the visual cortex, precise spike timing is not sufficiently reliable to play a role in the representation of visual information.

To challenge this claim, we made simultaneous recordings of neuronal activity from up to 32 electrodes in the visual cortex of anaesthetized cats while presenting simple visual stimuli, e.g. moving bars. For each neuron, we computed the preferred time at which it fired action potentials relative to all other neurons. This analysis reveals a preferred temporal sequence in which neurons tend to fire (the *firing sequence*).

We found that preferred firing sequences operated within a very short period of time – their total duration rarely exceeded 10 ms. Yet, firing sequences precisely reflected stimulus properties, and repeated reliably even over several hours of recording. The precision with which they changed in response to changing stimulus properties was equal to that of firing rates. Moreover, firing sequences and firing rates seemed to complement each other, as certain stimulus properties were reflected more accurately by firing rates while others were encoded more efficiently by the temporal sequences of firing.

In conclusion, despite operating at the time scale of just a few milliseconds, preferred temporal sequences of action potentials carry stimulus-related information with high precision. Firing sequences can thus serve as a neuronal code in the visual cortex and complement firing rates in the representation of visual information.