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Self-organization of information processing in developing neuronal networks

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Human brains possess sophisticated information processing capabilities, which rely on the coordinated interplay of billions of neurons. Despite recent advances in characterizing the collective neuronal dynamics, however, it remains a major challenge to understand the principles of how functional neuronal networks develop and maintain these processing capabilities. A popular hypothesis is that neuronal networks self-organize to a critical state [1-3], because in models, criticality maximizes information processing capacities [4-6]. This predicts that biological networks should develop towards a critical state during maturation, and at the same time processing capabilities should increase. We tested this hypothesis using multi-electrode spike recordings in mouse hippocampal and cortical neurons over the first four weeks *in vitro*. We showed that developing neuronal networks indeed increased their information processing capacities, as quantified by transfer entropy and active information storage [6-8]. The increase in processing capacity was tightly linked to decreasing the distance to criticality (correlation $r = 0.68$, $p < 10^{-9}$; $r = 0.55$, $p < 10^{-6}$ for transfer and storage, respectively). Thereby our results for the first time demonstrate experimentally that approaching criticality with maturation goes in hand with increasing processing capabilities.

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