Systematic Variation in Cytoarchitectural Landscapes in the Isocortex of Primates and Rodents

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Abstract

Two often-overlooked features of information processing architectures in brains are their scalability and evolvability.

Evolution of the Isocortex

Here we examine these features as they emerge from conserved developmental programs generating the isocortex (a.k.a neocortex) in mammals, where the area of the isocortex varies over several orders of magnitude. The isocortex is not isotropic, in two interesting ways. First, the flow of information from sensory systems proceeds from caudal to rostral: primary visual cortex and auditory cortex send their information forward, in the rostral direction, and in the somatomotor system more general levels of motor organization lie rostral to primary somatomotor cortices. Thus, information processing varies across the cortical sheet with higher stages of information processing and integration generally occurring at progressively more rostral locations. Second, we now know in primates that the number of neurons per "cortical column" along with neuron density decreases progressively from caudal to rostral in the isocortical sheet. Here we investigate how this feature relates to brain size.

We previously showed that the isocortex of several primate species is characterized by a systematic increase in neuron numbers (layers I-VI) per unit of surface area from its rostral (i.e., frontal cortex) to caudal pole (i.e., primary visual cortex; Cahalane, Charvet, and Finlay 2012). Whether these trends are observed in other taxonomic groups such as rodents and whether cortical layers also vary systematically across the isocortical sheet has not been established. Using standard stereological measures, we estimate neuron numbers in layers V-VI and layers II-IV per unit of cortical surface area across the isocortical sheet of three rodent species (hamster, *Mesocricetus auratus*; agouti, *Dasyprocta azarae*; paca, *Cuniculus paca*) and three primate species (owl monkey, *Aotus trivigratus*; tamarin, *Saguinus midas*; capuchin, *Cebus apella*). We find that the greater the isocortical area (or neuron number), the steeper the rostro-caudal gradient in neuron number per column. Most of the variation in neuron numbers under a unit of cortical surface area is generated by layer II-IV neurons (Charvet, Cahalane, and Finlay 2013).

We suggest that one organizational feature intrinsic to the isocortical sheet is thus the progressive "compression" of information from its caudal to rostral pole, considering both the number of neurons per column, and the size of cortical areas. The larger the cortex, the more profound is this compression. This central anisotropy in the cortical sheet is supported across species by a conserved rostro-caudal gradient in the timing of neurogenesis in development. We propose that this automatically generates the scaling we describe here across a range of isocortex sizes. This organizational feature, in addition to the simple increase in number of neurons, may account for the increased computational capacities of larger brains in mammals.

References

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