What factors drive differences in cortical representation of the body? Influence of innervation density, stimulus statistics and resource constraints.

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Abstract

Cortical topographic representations in sensory systems often exhibit non-proportional scaling to the size of input regions, with some regions magnified greatly beyond their physical size. In touch, the fingertip representation occupies a much larger cortical region compared to other parts of the body. Similarly, the fovea is magnified in the visual cortex. What drives this allocation regime? Several reasons have been proposed. One possibility is that allocations simply reflect afferent densities across the body, for example, the greater innervation of the fingertips and fovea. Another factor is the typical usage of body parts, resulting in variations in stimulus statistics. For instance, hands play a crucial role in everyday interactions and object manipulation, and the fingertips tend to have higher contact frequencies. In vision, representations have been successfully studied using mathematical models based on efficient coding principles. Building on this work in touch, we consider how regions of varying receptor densities and contact statistics may be allocated given some restriction on the amount of neural resources available- a sensory bottleneck. We find that the width of this bottleneck is a crucial factor in optimal resource allocation, inducing either expansion or contraction of input region representation. Both receptor density and stimulus statistics affect representation and jointly determine allocation for wider bottlenecks, where more neural resources are available. Additionally, we consider a model system, the star-nosed mole, where both density and usage of their tactile rays have been extensively studied, and find a correspondence between the predicted and empirical cortical allocations.

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