Neurobiological explanation of fast mapping in word acquisition: A brain-constrained cortex model

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Abstract

Children's striking capacity to learn basic aspects of word meaning in very few learning events, referred to as fast-mapping, has been demonstrated extensively by behavioural and cognitive studies, but the neurobiological mechanisms underlying fast-mapping remain elusive. Classical cognitive theories that propose a slow, gradual consolidation of novel semantic associations into the neocortex cannot account for such rapid learning. Furthermore, at the neural and cortical level, it is unclear how plasticity and connectivity could explain the formation of distributed semantic circuits across the cortex in only a few presentations. We examine the biological mechanisms underlying fast-mapping using a twelve-area neurobiologically constrained cortex model mimicking anatomical and physiological features of a range of frontotemporal-occipital areas. This complements early modelling attempts that have either been highly abstracted or have captured only a gradual semantic learning mechanism. Equipped with Hebbian learning and using a two-stage word learning process, the neural model demonstrates the mapping of word forms onto referents and the emergence of distributed semantic circuits with category-specific topographies in just a few presentations (ca. 10). We uncover several important predictions regarding fast-mapping: that it relies on a pre-existing conceptual framework, that modality-preferential areas, as well as semantic hubs, are vital to support efficient integration of representations, and that it does not depend on, but can be modulated by, attention. The modelling approach used here also demonstrates that Hebbian learning, cortical connectivity, realistic neural dynamics, and a two-stage learning process are sufficient to account for rapid associative semantic learning.