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NEST Replication of a Brain-Constrained Model of Semantic Grounding with Spiking Neurons and Brain-like Connectivity

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This work presents a first step towards scaling up a previously published brain-constrained model of semantic grounding. The original model explored the neural mechanics of category-specific cell assembly formation through the learning of action and object words (Tomasello et al., 2018). This initial phase focuses on replicating the original findings in NEST, to lay the groundwork for future expansion, including scaling the network. The ported model replicates the original 12-area structure original auditory and visual processing as well as articulatory motor and hand motor areas with three regions per system, for a total of 12 areas, each containing 625 excitatory and 625 inhibitory neurons. The model implements several brain constraints: (i) within-area connections are sparse and local, (ii) between-area connections are implemented in accordance with neuroanatomical studies, (iii) synaptic weights are modified by Hebbian learning rules of long-term potentiation and long-term depression, (iv) excitatory neurons are spiking and noisy and (v) neural activity is regulated through local and global mechanisms. The model was trained on correlated patterns in primary sensorimotor 'cortices', with patterns either encoding action or object words. Distributed but discrete cell assembly circuits emerged with category-specific topographies. Differences were found in the motor and visual cortices, and, notably, in highly connected 'semantic hub'areas that integrate information from various modalities. Our results indicate that both semantic hubs and category-specific areas emerge from the interplay of neuroanatomical connectivity and correlated neuronal activity during language learning, offering a neuromechanistic explanation for various findings on semantic grounding.

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References

Tomasello, R., Garagnani, M., Wennekers, T., & Pulvermüller, F. (2018). A Neurobiologically Constrained Cortex Model of Semantic Grounding With Spiking Neurons and Brain-Like Connectivity. Frontiers in Computational Neuroscience, 12, 88. https://doi.org/10.3389/fncom.2018.00088

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