Towards a Material Basis for Symbols

Researchers at Freie Universität Berlin and at the University of Plymouth use novel network models for understanding the human ability to manipulate symbols and language

Our ability to understand and produce meaningful symbols can only be explained based on realistic models of the underlying mechanisms. These mechanisms are brain mechanisms realized in the interplay of nerve cells in the human brain. Recent years have led to major advances in the investigation of the underlying materials, revealing, for example, novel features of the connectivity structure of the human cortex, along with surprising, even human-like capacities of artificial neural networks. A novel approach, called *brain-constrained modelling*, now uses such recent neurobiological material evidence at different levels of spatial resolution to make neural networks more realistic in order to work towards mechanistic counterparts of specifically human abilities.

A recent paper in *Nature Reviews Neuroscience* highlights the novel research strategy: Neural networks bridging between the microscopic level of nerve cell function, the mesoscopic level of interactions in local neuron clusters and the macroscopic level of interplay between these clusters and even larger brain parts are used to approximate human brain structure and function at different levels. Novel experimental evidence is brought in at these different levels, for example by implementing between-area connectivity structure as revealed by diffusion weighted imaging and probabilistic tractography or the local neuronal interactions between excitatory and inhibitory neurons within a cubic millimeter of cortex. The brain constrained models are then used to simulate human cognitive functions to relate them to parameters of the neuronal material that have changed in brain evolution – for example between macaques and humans. Relating functional cognitive changes to alterations in their material basis may facilitate a better understanding of the functional advances these well documented structural changes enable.

Prof Pulvermüller from the Department of Philosophy and Humanities of the Freie Universität explains the need for the novel approach as follows: “We know a lot about new evolutionary inventions realized in the human brain, but what we do not know is what the invention of a novel fiber bundle or cortical area functionally contributes to cognition. A fiber bundle as such is a rather dumb piece of material. Only in its functional interplay with other materials does it obtain any functional significance and, ultimately, gives rise to symbolic meaning.” Prof Thomas Wennekers from the School of Computing of Plymouth University adds: “Most of our current neural networks are still much too far away from the structures of brain-immanent networks. To simulate the basis of human cognition and language at a not too unrealistic level, it is necessary to translate much more of the recently acquired structural knowledge into sophisticated artificial networks.”

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Humboldt Universität zu Berlin and funded by the Deutsche Forschungsgemeinschaft, Pulvermüller and his team are now systematically approaching material-based answers to questions such as the following: How can humans learn a vocabulary of 10,000s of words whereas our closest relatives are normally stuck with 10s? How is it possible that little children quickly interlink signs with meanings, upon only one experience in the extreme, although our closest relatives have great difficulty building such links and neural networks require excessive time for learning them? By which mechanisms can we build abstract concepts and what contribution (if any) makes language to this process? (… and many others)

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Links:

Brain Language Laboratory at the Freie Universität: https://www.geisteswissenschaften.fu-berlin.de/v/brainlang/research/Current-Research/MatCo-Project/index.html

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