# Mechanisms of Self-Organisation bridging the Gap between Low- and High-level Cognition.

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## Abstract

High-level cognition requires adequate representations of skills and knowledge, heavily dependent on various forms of memory, i.e. our explicit and implicit expectations about the world. From a perspective of self-organisation, the functioning and development of the involved memory traces can be accounted for by two, interacting low-level mechanisms, both based on the notion of a dynamic equilibrium, i.e. an excitation loop.

*Loop propagation.* According to Hebb's well-known proposal, simultaneous neuronal excitation produces assemblies of neurons, forming – at the functional level – a network of memory traces. In this conceptual network [1], [2], we represent the connection of one assembly with another as a loop. An assembly's loop maintains its excitation and thus functions as a current expectation. Each assembly necessarily has a critical threshold, i.e. a threshold above which the excitation level of an assembly ignites [3]-[5], i.e. increases autonomously without further input from outside. Autonomous excitation growth plays an important role in the selective, divergent or convergent, propagation of excitation loops, similar to synfire chains [6]. At the functional level, the critical threshold is used to distinguish various forms of memory in cognitive processing.

*Variable binding as the closure of a context loop.* Whereas as a cell-assembly originates from feature binding, new combinations of cell-assemblies require the much less understood process of variable binding [7]. If we consider a cognitive system from the perspective of self-organisation, we cannot assume that all possible combinations of the expectations of its environment are directly available at all times. Therefore, the system needs binding in order to generate new, temporary combinations instantaneously. Within a conceptual network, this binding takes place by means of a temporary connection and occurs between two simultaneously excited assemblies or between an assembly excited together with a pattern in a neural structure called the spatial map. Each temporary connection involves an existing neural pathway and – at the functional level – enables re-entrant processing. The two neural spiking patterns involved become specific to each other because only these two patterns have a compatible role in the context of a cognitive process. At the neural level, this means that only for them their spikes are in phase. In the network, the context consists of a previously excited sub network of assemblies, i.e. previous expectations. The sub network contains a pathway leading from one of the temporarily connected items to the other. This pathway is essential to the spike resonance necessary for the temporary connection closing the context loop.

In order to ensure a robust variable binding in the network, temporary connections emerge in a rapid, serial process within the sub network of each context. Consistent with the perspective of self-organisation, this condition may foster the development of representations of sequence at the global level, for retaining the order of individual items, as well as at local levels, for retaining the order of items specific to a larger chunk, as in the letters of a word.

Based on computer simulations of the two mechanisms in the network, predictions for new behavioural experiments on word recognition, letter identification, and change blindness will be discussed, as well as ERP studies on masked priming. Generalisations for language will be given.

[1] P. H. de Vries and K. R. van Slochteren, "The nature of the memory trace and its neurocomputational implications," *J. Comput. Neurosci.,* vol. 25, pp. 188-202, 2008.

[2] P. H. de Vries, "Conditions for Cognitive Self-Organisation Implied by Visual-Word Processing," *Manuscript Submitted for Publication,* 2019.

[3] V. Braitenberg, "Cell assemblies in the cerebral cortex," in *Theoretical Approaches to Complex Systems*, R. Heim and G. Palm, Eds. Berlin: Springer, 1978, pp. 171-188.

[4] C. R. Huyck and P. J. Passmore, "A review of cell assemblies," *Biol. Cybern.,* vol. 107, *(3),* pp. 263-288, JUN, 2013.

[5] G. J. Dalenoort, "The representation of tasks in active cognitive networks," *Cognitive Systems,* vol. 1, *(3),* pp. 253-272, 1985.

[6] M. Abeles, G. Hayon and D. Lehmann, "Modeling compositionality by dynamic binding of synfire chains," *J. Comput. Neurosci.,* vol. 17, pp. 179-201, 2004.

[7] J. Feldman, "The neural binding problem(s)," *Cognitive Neurodynamics,* vol. 7, *(1),* pp. 1-11, FEB, 2013.