Specificity versus associativity from correlation-based plasticity.

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Many cognitive tasks require association of two stimuli to produce a response that differs from the response to either stimulus alone. For example, in the first phase of an associative transitive inference task [1], rats are presented with containers identifiable by a single cue odor (“A” or “X”) then a choice of two containers with odors (“B” or “Y”). If they dig in the container with odor “B” following cue “A” they find a reward, as they do if they dig in the container with odor “Y” following cue “X”. Thus an association must be learnt that “A” predicts “B” and “X” predicts “Y”. To successfully make the correct response of “dig” in the container whose odor matches the one predicted for reward, but to “switch” to the other container if it does not match, the rat must respond using logic equivalent to exclusive-or (XOR). A single set of connections from inputs to outputs cannot be used to solve such logic --- a “hidden” layer is essential. In the case of odor association, neurons responsive to a specific pairing, “A and B” must arise in this intermediate hidden layer. It is important that such neurons, which can then activate a “dig” response, do not respond to “A and Y” or “X and B”. In this paper we analyze how an initially randomly connected network of spiking neurons can develop the necessary associativity and specificity to enable correct responses to the task. For example, we find that spike-timing dependent plasticity (STDP) tends to “over-associate” so cells responding to a combination of inputs (“A and B”) later respond also to “A” alone. However, the more recently characterized long-term potentiation of inhibition (LTPi), counters such “A” to “AB” excitation (see Figure), by generating cross-inhibition that is essential to produce and maintain specificity in the circuitry. We discuss how the results of these different plasticity mechanisms can be distinguished in the development of neural activity patterns during training in vivo.

Figure: Final pooled connectivity and example spike patterns following unsupervised learning via STDP and LTPi in a random network with the inputs shown. A to AB excitation is countered by inhibition.

References