A Hebbian learning rule mediates asymmetric plasticity in aligning sensory representations

Abstract:

In the brain, mutual spatial alignment across different sensory representations can be shaped and maintained through plasticity. Here, we use a Hebbian model to account for the synaptic plasticity that results from a displacement of the space representation for one input channel relative to that of another, when the synapses from both channels are equally plastic. Surprisingly, although the synaptic weights for the two channels obeyed the same Hebbian learning rule, the amount of plasticity exhibited by the respective channels was highly asymmetric and depended on the relative strength and width of the receptive fields (RFs): the channel with the weaker or broader RFs always exhibited most or all of the plasticity. A fundamental difference between our Hebbian model and most previous models is that in our model synaptic weights were normalized separately for each input channel, ensuring that the circuit would respond to both sensory inputs. The model produced three distinct regimes of plasticity dynamics (winner-take-all, mixed-shift, and no-shift), with the transition between the regimes depending on the size of the spatial displacement and the degree of correlation between the sensory channels. In agreement with experimental observations, plasticity was enhanced by the accumulation of incremental adaptive adjustments to a sequence of small displacements. These same principles would apply not only to the maintenance of spatial registry across input channels, but also to the experience-dependent emergence of aligned representations in developing circuits.

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