# A Dynamical Model of Binding in Visual Cortex During Incremental Grouping and Search

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Binding of visual information is crucial for several perceptual tasks. To incrementally group an object, elements in a space-feature neighborhood need to be bound together starting from an attended location (Roelfsema, TICS, 2005). To perform visual search, candidate locations and cued features must be evaluated conjunctively to retrieve a target (Treisman&Gormican, Psychol Rev, 1988). Despite different requirements on binding, both tasks are solved by the same neural substrate. In a model of perceptual decision-making, we give a mechanistic explanation for how this can be achieved (Fig. 1). The architecture consists of a visual cortex module and a higher-order thalamic module. While the cortical module extracts stimulus features across a hierarchy of spatial scales, the thalamic module provides a purely spatial relevance map. Both modules interact bidirectionally to enter locations of task-relevance into thalamus, while allowing integration of context with local features within cortical maps. This integration realizes the model's binding mechanism. It is implemented by pyramidal neurons with dynamical basal and apical compartments performing coincidence detection (Larkum, TINS, 2013). The basal compartment is driven by bottom-up feature information and produces the neuron's output, the apical compartment computes top-down contextual information akin to an interaction skeleton (Roelfsema&Singer, Cereb Cortex, 1998). Apical-basal integration yields an up-modulation in neuron activity binding it to the attended configuration. Gating information from thalamus restricts this integration to task-relevant locations (Saalman&Kastner, Curr Op Neurobiol, 2009). By model simulations, we show how altering the apical compartment's operation regime steers binding to either perform search or incremental grouping.

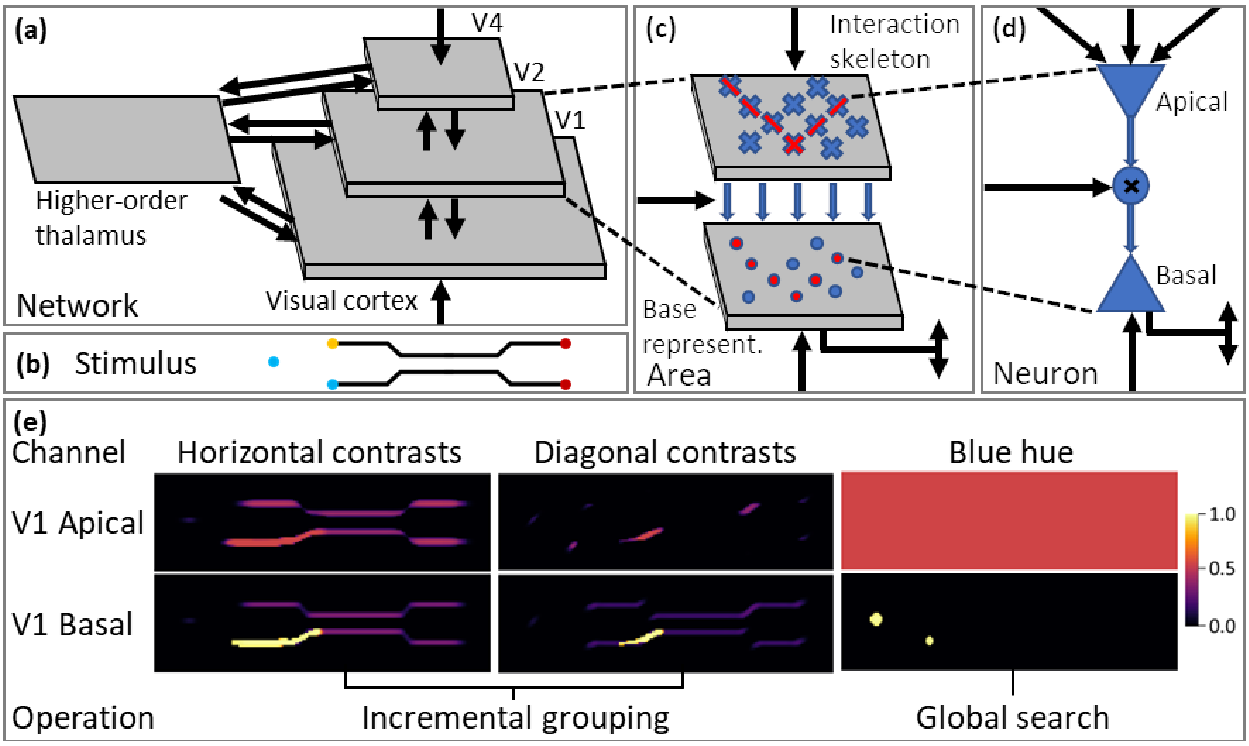


**Figure 1:** Architectural overview **(a-d)** and exemplary results **(e)**. **(a)** Higher-order thalamic relevance map and ventral visual cortex module interact bi-directionally. Connections are implemented by convolution kernels. **(b)** An RGB stimulus is provided as input to the model (stylized depiction). **(c)** Each cortical area extracts visual features from the bottom-up stream and computes an interaction skeleton based on top-down information. Higher-order thalamic input gates integration of interaction skeleton information into the space-feature representation. **(d)** Two-compartment pyramidal cells perform binding of the different representations based on three-way coincidence from the different streams. Compartments are modeled in terms of differential equations. **(e)** Apical potentials and basal activities in model area V1 for different feature channels and apical operating regimes. While the system is conditioned to perform incremental grouping, it exhibits different interaction skeletons and activities across horizontal and diagonal orientation channels (left, middle). If conditioned to perform global search for blue cues, the blue hue channel is apically biased globally, but up-modulation of basal activity is only exhibited at locations of coinciding bottom-up features (right).

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