

# Plasticity in the barn owl auditory localization system: A spiking neuronal model

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Auditory localization behavior in barn owls is mediated by the integration of topographically encoded visual and auditory space maps (see fig. 1). In juvenile owls, disruption of this alignment between auditory and spatial representations by exposure to spectacles that laterally shift the visual field of view results in behavioral adaptation over the course of several weeks. It has been reported in literature that this adaptation is brought about via rewiring in the neural circuits that encode these space maps - new connections are formed between existing neurons so as to encode the new audio-visual associations (see fig. 2). Visual input guides this plasticity in a topographic manner, and it was recently established that the "error signal" is encoded in the firing delay of neurons in the external nucleus of the inferior colliculus (ICX). A good computational synthesis of plasticity in this system that takes these key observations into account is currently lacking.

In this work, we use leaky integrate-and-fire neurons to model the key elements of the midbrain interaural temporal difference (ITD) processing pathway in the auditory localization circuit. Our main interest is in the computational mechanisms via which the error signal can trigger and implement plasticity. We demonstrate that a spike-time dependent learning rule, coupled with an activity-dependent mechanism that induces growth, can account for the essentials of circuit-level adaptation associated with prism experience. We point out the importance of inhibition for both the normal functioning of this circuit, and for prism-induced plasticity. We predict that the delay in the firing of ICX neurons is only one half of the error message, serving to signal the presence of misalignment, while the firing pattern itself is the other, which can serve to trigger axogenesis. We also discuss candidate mechanisms for activity-induced growth.

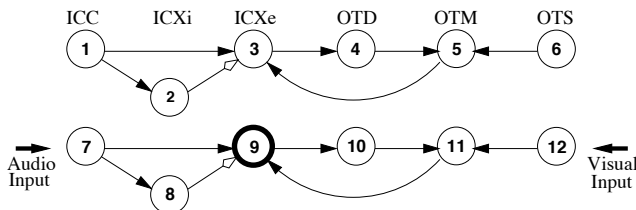


Fig. 1. Schematic of the midbrain interaural temporal difference (ITD) processing pathway in a normal juvenile owl. Neurons are depicted as circles and numbered, excitatory connections are represented as arrows with filled heads, and inhibitory ones with open heads. Neurons in a given layer are arranged in the same column. Auditory input arrives at the central nucleus of the inferior colliculus (ICC, neuron #7) and visual input from the same location arrives at the superior layer of the optic tectum (OTS, neuron #12). OTD and OTM refer to the deep and medial layers of the optic tectum respectively. ICXi and ICXe refer respectively to inhibitory and excitatory neurons in the external nucleus of the inferior colliculus (ICX).

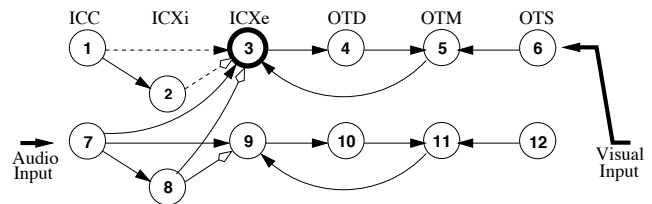


Fig. 2. Schematic of the network after structural plasticity and behavioral adaptation to chronic prism exposure. New connections project to ICXe #3. As a result, its auditory receptor field has shifted such that it now receives matched auditory and visual stimuli in the presence of prisms. Innate connections that are depotentiated are shown with dotted lines.