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Local inhibition shapes afferent excitatory drive of output neurons in the songbird basal ganglia network

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Background

Song learning in songbirds shares striking similarities with speech acquisition in humans. Songbird brains contain a neural network dedicated to song learning, called the anterior forebrain pathway, which is homologous to the mammalian basal ganglia (BG)-thalamo-cortical loop. A structure called Area X contains both striatal and pallidal components of the BG circuit and projects to the medial portion of the dorsolateral nucleus of the thalamus (DLM), where pallidal cells make powerful GABAergic synapses that could drive firing through post-inhibitory rebound mechanisms. We aim to determine the transformation undergone by input signals through avian BG.

Methods

We recorded the extracellular activity of i) Area X pallidal neurons and ii) DLM neurons in response to electrical stimulation of Area X afferent structures, namely HVC (used as a proper name) and the lateral magnocellular nucleus of the anterior nidopallium (LMAN). Recordings were made from adult male zebra finches, either in urethane-anesthetized *in vivo* preparation or in brain slices.

Results

In vivo, almost all pallidal neurons of Area X displayed a rapid excitation in response to stimulation in either HVC (n = 48) or LMAN (n = 20). The excitation was often followed and/or, surprisingly, preceded by inhibition. The resulting excitatory peak in these responses was very short. Its average latency was 11.6 ms (n = 44), and its duration was 8.8 ms, while average inhibition latency was 10.4 ms (n = 26). We found no difference between the effect of stimulating HVC vs LMAN. We also found through antidromic stimulation that most Area X pallidal cells project to DLM (7/11), and that the giant terminals of these cells recorded in DLM (n = 17) displayed responses similar to those of other pallidal cell somata recorded within Area X (n = 31). After application of the $GABA_A$ receptor blocker picrotoxin in Area X, inhibitory components of the pallidal responses were absent and the excitatory component became longer, with an average duration of 17 ms (n = 10). *In vitro* recordings confirmed that pallidal responses to HVC fibers stimulation are broadened by picrotoxin application. In DLM neurons *in vivo*, HVC stimulation evoked rapid and precise excitatory responses, with an average latency of 17.8 ms (n = 12).

Conclusion

Afferent fiber stimulation evokes a short excitatory response in pallidal cells, which is shaped by an inhibitory network in Area X. This response profile could play various roles in driving firing in DLM, either providing a strong inhibition allowing subsequent post-inhibitory rebound, or shortening rebound firing induced by a previous pause.