

Multiplicative Auditory Responses in the Midbrain of the Barn Owl

Brian J. Fischer¹, Jose Luis Peña², and Masakazu Konishi¹

¹California Institute of Technology, ²Albert Einstein College of Medicine

Space-specific neurons in the barn owl's auditory space map gain spatial selectivity through tuning to combinations of the interaural time difference (ITD) and interaural level difference (ILD). The combination of ITD and ILD in the subthreshold responses of space-specific neurons in the external nucleus of the inferior colliculus (ICx) is well-described by a multiplication of ITD and ILD [1]. It is unknown, however, how ITD and ILD are combined at the site of ITD and ILD convergence in the lateral shell of the central nucleus of the inferior colliculus (ICcl) and therefore if ICx is the first site in the auditory pathway where multiplicative tuning to ITD and ILD occurs. We used extracellular recording of single neurons to determine how ITD and ILD are combined in ICcl.

By comparing additive and multiplicative models of neural responses we show that ITD and ILD are combined nonlinearly in ICcl, but the interaction of ITD and ILD is not uniformly multiplicative over the sample. A subset of the neural responses are well-described by a multiplicative interaction of ITD and ILD indicating that ICcl is the first site where multiplicative tuning to ITD and ILD occurs. ICx, however, is the first site where multiplicative tuning is observed consistently. While the fit to the data is better for the multiplicative model than the additive model for 94% of the cells, there are properties of the neural responses to ITD and ILD that are not consistent with multiplication. ITD tuning curves of some ICcl neurons shifted with changes in ILD and vice versa. In several neurons, ITD tuning disappeared at large positive or negative ILD values while neurons continued to respond to the sound. Also, most neurons showed changes in the shape of the ILD tuning curve for different ITDs.

We constructed a network model to determine if a linear combination of the responses to ITD and ILD observed in ICcl is sufficient to produce the multiplicative subthreshold responses to ITD and ILD seen in ICx [1]. In this model we treat ICcl as a set of hidden units that combine ITD and ILD in a diverse set of responses. For each ICx subthreshold response examined, it was possible to find connection weights between the ICcl units and the ICx unit so that the correlation coefficient between the ICx data and the model approximation was greater than 0.99. These results support a model where multiplicative tuning to ITD and ILD develops in stages in the barn owl's inferior colliculus.

Acknowledgments

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References

[1] Auditory spatial receptive fields created by multiplication. J.L. Peña and M. Konishi, *Science* 292:249-252, 2001.