Spike-Frequency Adaptation in the Auditory Preprocessing Module of Crickets

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1 Introduction

Neural information processing of sensory information needs to adapt to changing environmental conditions on various time scales. By generating invariant object representations that are robust against different environmental conditions, adaptation is important for reliable object recognition and classification. Here, we analyze adaptation properties of two interneurons in the auditory system of crickets. In particular we are interested in the following two questions:

1. Does adaptation generate a robust stimulus representation at different sound intensities and thereby create acoustic object invariance already at the first level of auditory processing in crickets?

2. Can our simple phenomenological adaptation model that is solely based on measurements of $f$-$I$ curves capture the dynamics of adaptation and predict the firing frequency of interneurons in response to dynamic stimuli correctly?

Female crickets recognize the song of a conspecific male from various distances. In the auditory system of crickets about 50 receptor neurons synapse onto two interneurons, the AN1 and the AN2, that ascend to the brain. The AN1 is excited by low frequency receptors only, that are tuned to the carrier frequency of the cricket’s song. The AN2 receives input from both low and high frequency receptors, but is less sensitive than the AN1.

2 Methods

We performed extracellular recordings of the AN1 and AN2 in the neck connective of cricket species from the genus Gryllus and Teleogryllus. For characterizing spike-frequency adaptation we measured the time course of the firing frequency evoked by low frequency (3–5 kHz) and high frequency (16 kHz) sound waves with constant amplitudes at intensities ranging from 30 to 90 dB SPL. By fitting a single exponential on the firing frequency we quantified the properties of adaptation on a timescale up to 200 ms.

By means of a phenomenological model for the firing frequency of an adapting neuron we predicted the firing-frequency response $f(t)$ of the neurons to various Gaussian white noise stimuli $I(t)$ based on their onset ($f_0(I)$) and steady-state $f$-$I$ curve ($f_\infty(I)$) and adaptation time constant $\tau$.

\[
f(t) = f_0(I - A) \quad \tau A = I - f_\infty^{-1}(f_0(I)) - A
\]


3 AN1 Teleogryllus oceanicus

Carrier frequency: 4.5 kHz

Adaptation time constant: 62 ± 14 ms
**4 AN2 *Teleogryllus oceanicus***

Carrier frequency: 16 kHz

Adaptation time constant: $68 \pm 8$ ms

**5 AN2 *Teleogryllus leo***

Carrier frequency: 16 kHz

Adaptation time constant: $65 \pm 13$ ms
6 Summary

Adaptation shifted the intensity-response curve of all interneurons to higher stimulus intensities. For the AN1, this shift was accompanied by a substantial reduction of the maximum firing frequency. The AN1 can adapt its intensity-response curve to different stimulus intensities over a range of 35 dB. Therefore it transmits information about the temporal structure of a stimulus almost independently of the mean stimulus intensity (Benda & Hennig (2005) submitted). The AN2 is less sensitive, but shows similar subtractive adaptation as the AN1. In contrast to the AN1, the maximum firing frequency of the adapted $f$-$I$ curves is independent of adaptation for the AN2.

7 Conclusion

1. Our data show, that the neuronal response is intensity invariant at the first level of auditory processing in crickets.

2. The adaptation model performs well in all cells, demonstrating that measurements of $f$-$I$ curves and adaptation time-constants are sufficient for describing the dynamics of adaptation.