Predictability of STRFs in auditory cortex neurons depends on stimulus class

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Abstract

The goal of this study was to predict neuronal responses based on STRF-estimates for different stimulus sets of primary auditory cortex neurons of Mongolian gerbils. Here we review results from STRF estimations after stimulation with frequency modulated (FM) tones, Dynamic Moving Ripples (DMR), as well as, prediction of responses to logatomes stemming from the Oldenburg Logatome Corpus (OLLO) data set [1]. Our results suggest that it is not merely the similarity of the presented power spectrum of stimuli that leads to better STRF predictions. We will suggest new STRF-approaches to categorize neuronal responses to more natural stimuli.

Index Terms: Spatiotemporal Receptive Field (STRF), auditory cortex, response prediction, logatome

1. Introduction

Auditory neurons are classically analyzed using spectrally and temporally simple stimuli (e.g. pure tones, clicks). One unresolved question is the predictability of responses to natural stimuli based on responses to such test stimuli. In the framework of STRF theory a neuron is considered as a signaltransforming element described by the stimulus transfer function:

\[ Y(t) = \int d\tau \cdot h(t-\tau) \cdot x(t-\tau) \] (1)

To address the predictability problem for frequency modulated (FM) tones we developed a set of stimuli that should in principle contain all necessary parameters of FM tones (FM-bank). Predictive value of these stimuli was compared to that of DMR stimuli [2] and logatomes. DMR stimuli satisfy certain theoretical requirements making them suitable for predicting neural responses to complex stimuli [2].

2. Results

2.1 STRF-estimation based on subcortical vs. cortical data sets

As expected, our data demonstrate that STRFs of cortical units show a much more complicated organization compared to STRFs of inferior colliculus (IC) units. Cortical STRFs were estimated from 16.67 minutes of FM-Bank stimulation or DMR stimulation, respectively. Comparison between STRFs of cortical and of IC units revealed that the STRF estimate of the IC unit has superior SNR-ratio, thus showing that a further increase in stimulation time is necessary to achieve comparable results in auditory cortex.

2.2 Cortical STRF-estimation from FM- and DMR-sets

Predictions of neuronal responses to FM-bank stimuli based on STRFs estimated from DMR and from FM-bank stimulation were compared. Predictability of IC responses was generally higher than of cortical responses. Predictions based on FM-bank stimulation were better in both IC and cortical units. In addition to the classical focal maxima, STRFs of some cortical units also displayed oblique structures not seen in IC units when FM-bank stimuli were used. Other STRFs that did not show a focal maximum but only oblique structures yielded generally good predictions (FM: \( r=0.66, p<10^{-14} \) vs. DMR: \( r=0.30, p<1.5\cdot10^{-5} \)). As an example, Fig. A shows a cortical unit with an "inverted" version of a classical STRF. For this unit, oblique structures could not be demonstrated using DMR stimulation. This observation points towards units exhibiting strongly non-linear processing of spectra showing FM-components.

2.3 STRF-prediction of neural responses to logatomes as a model for natural stimuli

To test the suitability of STRF-estimates for the prediction of neuronal responses to more natural stimuli a random selection of logatomes (30 min) was used. A STRF based on logatomes is shown in Fig. B. The prediction of responses to logatomes is possible and in the range of DMR predictions (best correlation was \( r=0.39, p<3.3\cdot10^{-5} \)). So, characterization of neuronal activity, especially for cortical neurons, cannot be achieved to full satisfaction by state-of-the-art STRF estimators.

3. Conclusions

Neuronal responses to FM components in artificial and logatome stimuli can be better predicted by the proposed FM-bank-based estimators of STRFs compared to the classical DMR-based estimators. Overall low levels of response prediction to natural sounds indicate the relevance of nonlinear mechanisms in response generation. Based on theoretical modeling we will propose combined stimuli classes for a better categorization of STRF-based neuronal responses to logatome stimuli.

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5. References