WASHINGTON STATE UNIVERSITY
VANCOUVER

Complementary effects of adaptation and gain control on sound encoding in primary auditory cortex

Jacob Pennington, Alexander Dimitrov and Stephen David

OREGON HEALTH & SCIENCE UNIVERSITY
OHSU

Auditory encoding is nonlinear

An auditory neuron's responses to simple synthetic stimuli do not reliably predict how it will respond to complex natural sounds [2].

Neurons can also respond differently to the same stimuli depending on the sensory context, such as the pitch or repetitiveness of recent sounds [3, 4].

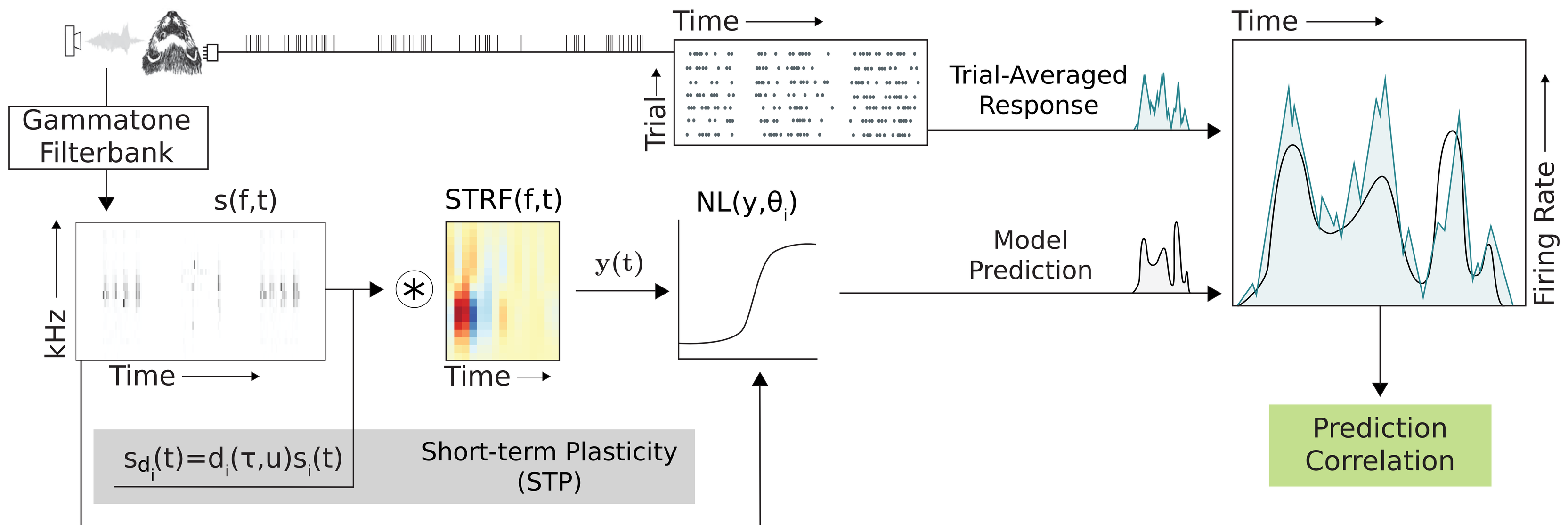
Many basic aspects of sound-evoked activity are captured by the linear-nonlinear spectro-temporal receptive field model (LN-STRF, abbr. LN) [1]. However, the LN model fails to explain many contextual effects [2].

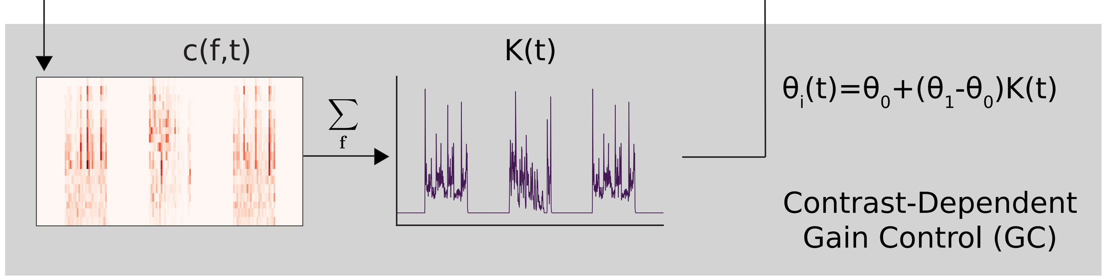
Models that account for contrast-dependent gain control (GC) and short-term plasticity (STP) each out-perform the LN model, but these models may be redundant [3, 5]. That possibility has been difficult to test, however, because the models were implemented separately and tested on different datasets.

The objective of this study was to determine the degree of equivalence between STP and GC models by performing a head-to-head comparison using the same software package and same natural sounds dataset for each model.

Four models of auditory encoding

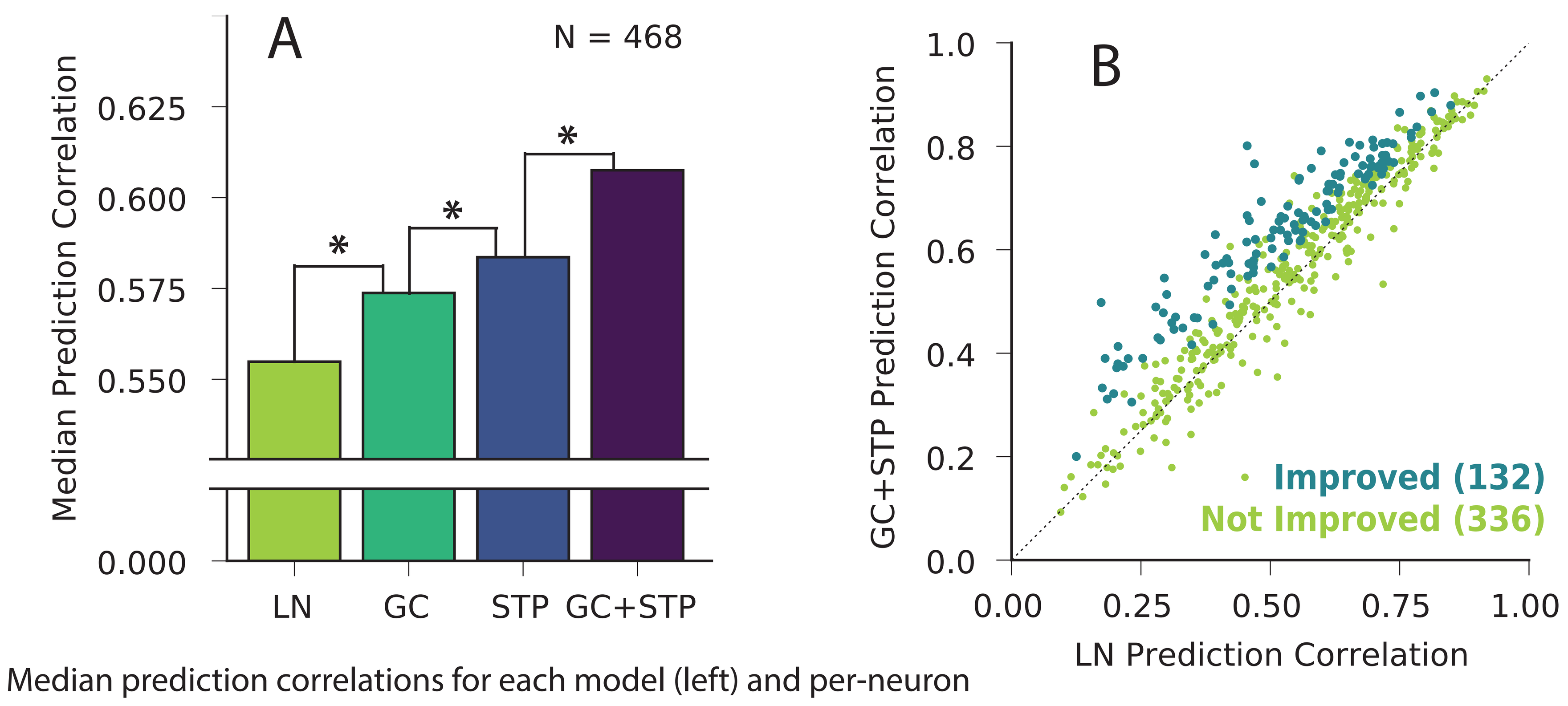
In general, the goal of an encoding model is to establish a mapping between a sensory stimulus and a neural response. The models used for this study proposed the following mapping, where the portions labeled STP and GC were optionally included or excluded to form four models.





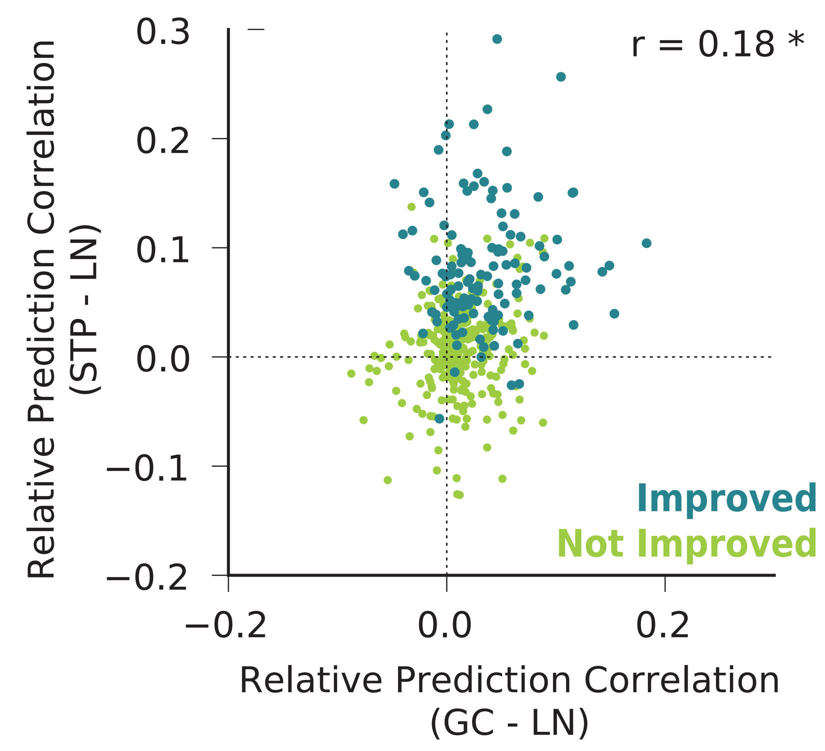
With a mapping identified, one can predict a neuron's response to a novel stimulus with a goal of maximizing the correlation between prediction and response.

A combined model significantly improves performance

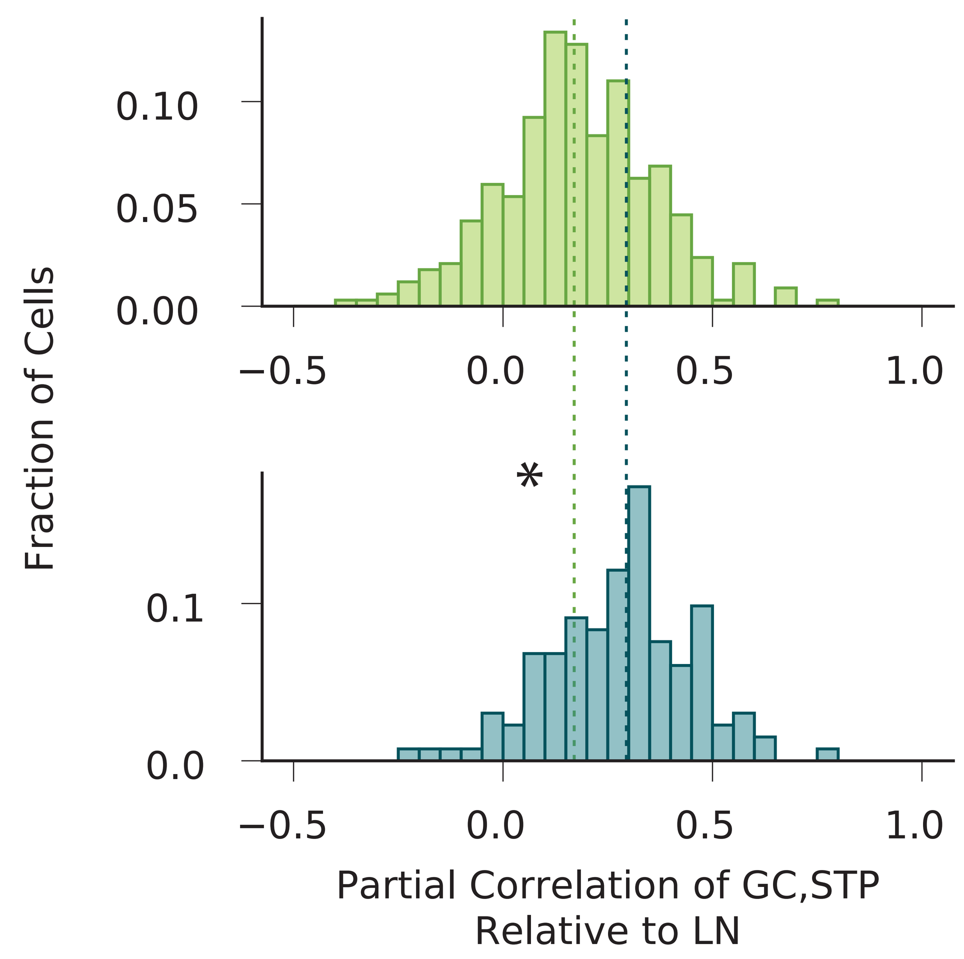


Median prediction correlations for each model (left) and per-neuron prediction correlations for the LN and combined models (right).
* denotes $p < 0.05$ (wilcoxon signed-rank test).

Limited equivalence between models



(TOP) Each point represents one neuron. Values were obtained by subtracting the prediction correlation for the LN model from the prediction correlation for the STP and GC models.



An equivalence score was assigned to each neuron, measured as the partial correlation between the predicted PSTHs of the GC and STP models relative to the predicted PSTH of the LN model.

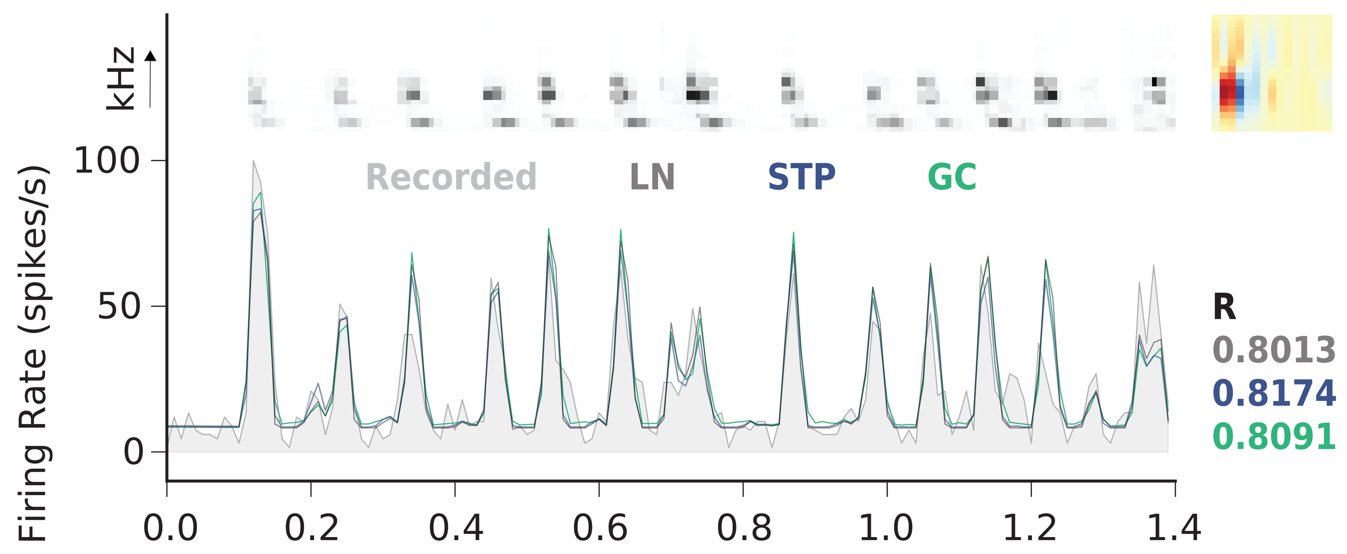
Conclusions and future work

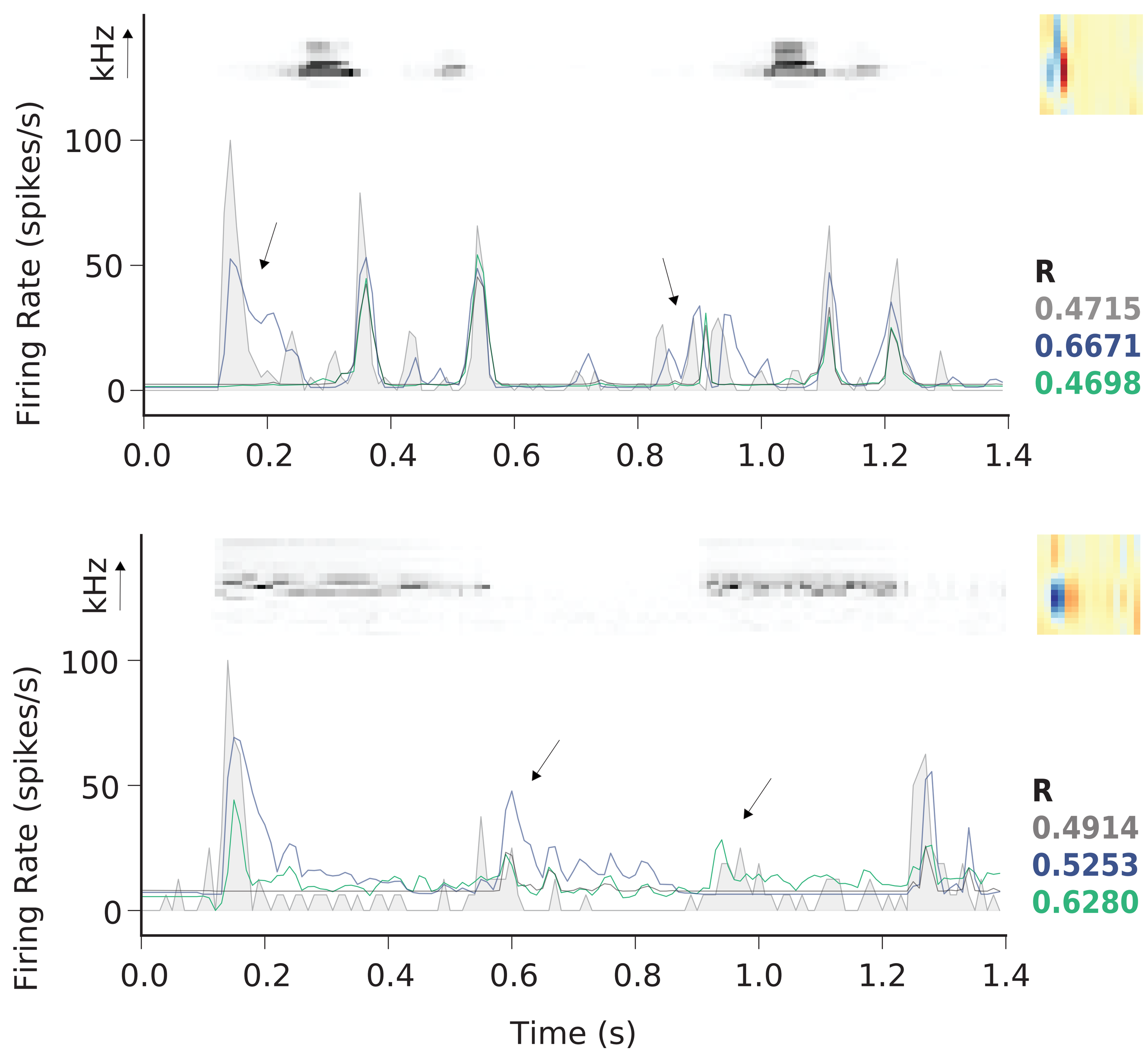
The STP and GC models are not equivalent for the natural sounds library that we used. Their combination clearly provides a synergistic boost in predictive power, and their predictions differ from the LN model in distinct ways.

Both models are therefore necessary in order to fully describe auditory neurons' nonlinear responses to natural sounds.

Future work will focus on implementing additional model architectures in the open-source software package used for this study (available at github.com/LBHB/NEMS) to enable similar comparisons.

The STP and GC models differ from the LN model in distinct ways





Model fits for three example cells. Within each panel, the stimulus spectrogram is shown across the top, the fitted STRF for the LN model is shown at the top right, the predicted and actual PSTHs are shown across the bottom, and the prediction correlations for each model are shown at the bottom right.

(LEFT) All three models predict the response about equally well.

(RIGHT,TOP) The STP model correctly predicts onset responses that the GC and LN models miss.

(RIGHT,BOTTOM) The GC model correctly predicts two onset responses that the LN model misses. The STP model also predicts the first onset response, but not the second.

References and Acknowledgements

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