Linear Modelling of Non-Linear Response Functions: Stimulus-Specific STRFs without Stimulus-Specific Adapation

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Neurons in the central auditory system are often described by the spectrotemporal receptive field or response function (STRF), conventionally defined as the best linear fit between the spectrogram of a sound and the spike-rate it evokes. Unfortunately, the true stimulus-response relationships of auditory neurons are commonly non-linear, and this makes interpretation of the best linear fits difficult. An STRF is assumed to provide an estimate of the receptive field of a neuron, i.e. the spectral and temporal range of stimuli that affect the response and whether the effects are excitatory or inhibitory. However, when the true response function is non-linear, the STRF will be stimulus-dependent, and changes in the stimulus properties can alter estimates of the polarity and spectrotemporal extent of receptive field components. We demonstrate through simulations that these effects can be dramatic. Even when uncorrelated stimuli are used, simple and biologically plausible neuronal non-linearities can produce STRFs with spurious receptive field elements, indicating contributions from time-frequency combinations to which the neuron is actually insensitive. Only when the distributions of the stimulus values are statistically independent does the STRF reliably indicate features of the underlying receptive field, and even then it gives only a conservative estimate of the spectrotemporal extent. One consequence of these observations, which we illustrate below using natural stimuli, is that any stimulus-induced change in an STRF could arise, at least in part, from a consistent but non-linear neuronal response to stimulus ensembles with differing higher-order dependencies, rather than from stimulus-driven adaptation in response properties. In combination with related work \cite{1}, our simulations demonstrate that non-linearities can lead to apparent stimulus-specificity in the shape and extent of a receptive field, as well as stimulus-specificity of response properties within a receptive field. Thus, while auditory receptive fields may well adapt to the statistics of different stimulus ensembles, stimulus-dependence of STRFs alone is not sufficient proof of such adaptation.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure.png}
\caption{Left, STRF estimate of a simple two-component multiplicative response function, derived from simulated responses to a database of environmental sounds \cite{2}. Right, STRF estimate of the same multiplicative response function, derived from simulated responses to a selection of Bach violin partitas. Each stimulus ensemble was de-correlated for STRF estimation using standard techniques \cite{3}.}
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References
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