A general framework explains receptive fields and plasticity in multiple sensory cortices

Andrew M. Saxe (asaxe@stanford.edu)
Department of Electrical Engineering
Stanford University, Stanford, CA 94305 USA

Abstract

What are the computational principles that underly receptive fields in sensory cortices? We present a comprehensive, quantitative analysis of the fit between current theoretical models and experimental data across primary visual, auditory, and somatosensory cortex.

Introduction

We use the word 'general' in three senses: first, we show that no specific algorithm has a decisive advantage in matching receptive field properties; rather, any instance of a broad class of sparsity inducing algorithms will perform comparably. Thus by 'general' we mean in part that there is a meta-algorithm, or set of principles, for generating plausible candidate algorithms: the method must attempt to preserve information about the input data, and encourage a sparse representation. Second, we show that the parameters governing the algorithmic implementations need not be chosen differently to accurately fit each modality; one set of parameters generalizes across modalities, and thus by 'general' we mean that these algorithms are not modality specific. Finally, we show that these algorithms also reproduce results from plasticity experiments. Hence these algorithms generalize to non-normal and even somewhat extreme manipulations of experience during rearing. Taken together, our results argue that one set of principles is shared across primary sensory cortices; that the parameters of the particular instantiation of these principles is shared; and that these principles are always active during rearing–be it normal rearing or altered rearing.

Methods and Materials

Our results are divided into two main experiments. The first experiment consists of an extensive set of simulations that quantitatively compare receptive fields measured in vivo to those generated by a variety of computational algorithms. We derive quantitative comparisons to Macaque primary visual cortex, Squirrel monkey primary auditory cortex, and Macaque primary somatosensory cortex. Each algorithm has a set of parameters governing its implementation. Using approximate Bayesian computation (ABC) (?, ?), we estimate the posterior distribution of these parameters for each sensory cortex separately, and for all three cortices jointly. This enables a quantitative Bayesian comparison of the hypothesis that these parameters are modality dependent with the hypothesis that they generalize across modalities. The second experiment consists of a qualitative evaluation of the ability of these computational algorithms to replicate the receptive field plasticity observed in V1, A1, and S1 in response to altered rearing conditions.

Learning algorithms

We use a

ICA

Sparse coding

Sparse autoencoder

Sparse restricted Boltzmann machine

K-means clustering

Binary sparse coding

Max sparse coding

Training data to simulate normal rearing conditions

Vision

Audition

Somatosensation

Comparisons to experimental data

Vision

Audition

Somatosensation

Estimating parameter posteriors using ABC

Training data to simulate plasticity experiments

Vision

Audition

Somatosensation

Results

Discussion