

Goals

Language is one of the most complicated phenomena in everyday life, and by far the most common means by which human beings interact with each other. Viewed as a dynamical system, it is fascinating that spatial (written) and temporal (spoken) patterns can couple brain states so effectively! A key capability for this process is the remarkable properties of the mammalian cochlea, an organ in the inner ear that translates the mechanical vibrations of sound into neural impulses. Our goals in this project are **to understand quantitatively the function of the cochlea** in the context of language, and **to study the characteristics of the local parameter space**, with an eye toward the evolution of the cochlea's capabilities (on the "slow time-scale" of evolution[5]).

Plan

We will begin by developing a computer simulation of the basilar membrane of the cochlea, the organ responsible for mechanical spectral analysis of incoming auditory stimulation[8, 9]. The basilar membrane can be approximated as a series of coupled mass-spring oscillators with different resonant properties [2, 7], as a cascade of filters [1], using finite element methods [10], finite difference methods [3], or a variety of other techniques. Our first task will be to evaluate each of these approaches for ease of implementation, biological accuracy, and mathematical elegance (or ease of analysis). After choosing and implementing a model, we will test the simulation by coupling the boundary conditions with recordings of actual speech. We will perform analysis on sensitivity and impulse response. Time permitting, we will pursue some of the following extensions:

- analyze the sensitivity of cochlear functions to various tuning parameters (such as the frequency of the incoming signal and/or the stiffness of the membrane) [11] and identify bifurcations
- develop a neural model of phoneme classification [6], which will be coupled to the output of the basilar membrane model
- attempt a mechanical cochlea [2, 4]
- implement a second, less mathematically elegant but empirically more accurate model (such as finite differences), and compare results

References

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