Course reader: *Applications of the Fourier transform*

- In this section I showed several examples of applications of the Fourier transform.

- One example was of gait behavior in a patient with Parkinson's disease and a healthy individual. An interesting observation of this example with that the width of a peak in a frequency band might contain useful or diagnostic information about the signal.

- Another example was narrowband spectral features in electrical brain data. These are called *neural oscillations*. Understanding the biophysical generation, computational importance, and clinical relevance of neural oscillations is a large topic in neuroscience, and is the core focus of research in my laboratory. An interesting observation that you see in neural oscillations is that although in the field we call them "narrowband," they're not always very narrow. Sometimes a spectral peak can be several Hz wide, and sometimes even 10s of Hz wide. These wide "narrow" peaks are due to non-stationarities, and when you look closely at these data, you'll see that the oscillations get faster and slower over time, in addition to increasing and decreasing in amplitude. The changes in amplitude and frequency have implications for how brain cells respond to sensory stimuli and transmit electrochemical signals to other brain cells.

- One of the biggest uses of the Fourier transform that doesn't involve visually inspecting the power spectrum for rhythmicity is a procedure called convolution. Historically, convolution was implemented in the time-domain as a time series of dot products between one signal and shifted versions of another signal. However, the convolution theorem shows that this time-domain operation is identical to the inverse Fourier transform of a pointwise multiplication between the Fourier spectra of the two signals. And because the FFT is so fast, this turns out to be a really efficient way to implement convolution.

- I showed an application of convolution in narrowband temporal filtering. Here the idea is to take the FFT of time series data, zero-out the frequencies that you are not interested in, and reconstruct the time-domain signal using the IFFT. Just make sure to avoid introducing sharp edges in the frequency domain, because this can create ringing artifacts in the reconstructed signal.

- Finally, I showed an example have the same concept but applied to images instead of time series.

- Both of these are examples of signal separation, because multiple signals are mixed in the time domain, but can be separated in the frequency domain.

- It's important to know that frequency domain-based signal separation will work only when the signals really are separable in the frequency domain. If the spectral content of the signals overlap, then narrowband filtering is unlikely to provide a good separation. If you are interested in learning more about signal separation and dimensionality reduction, then I'll have a course on this topic soon!