# Previous Research

## Papers

**Räsänen et al (2015) Fluctuations of Hi-Hat Timing and Dynamics in a Virtuoso Drum Track of a Popular Music Recording.**
Looks at both amplitude and timing fluctuations but only over long terms. Focuses quite a bit on the "highly sensitive onset detection".

Makes the point that $1/f$ (or fractal) fluctuations found in the drumming are also found in other "human-generated time series"

> "According to recent studies, such fluctuations ($1/f$) also lead
> to a favored listening experience."

> "To the best of our knowledge, the correlation properties of amplitude (i.e., loudness) fluctuations of beats in rhythms have not been scrutinized as yet."

> "Previously, it has been found that microtiming deviations without LRCs do not affect the listener groove ratings, or even correlate negatively with them. On the other hand, groove ratings can be changed with other aspects in the rhythmic structure, e.g., with syncopation. Here we focus on timing and loudness variations that occur naturally when a drummer plays to a piece of music, and suggest that they may also contribute to the groove. However, we do not provide an exhaustive treatment of groove from a musicological point of view."

> *"I like the single-handed method, because it's a lot smoother feel. For instance in the Michael McDonald record "I Keep Forgettin", I tried doing the alternating stroke method of doing 16ths, and it sounded just too stiff and staccato for me.*" - Drummer Jeff Porcaro
> Interesting statement from the drummer of the song analyzed in the paper. What he says here is that by being forced to use a single hand to play the pattern instead of two, it felt better and less stiff. This raises a whole other interesting question about why that might be, what muscle or nerve delay could be responsible for influencing the feel of a part with one hand that is less present on a part played by both?

> "Clear evidence of LRC fluctuations in 16th note hi-hat intervals was found. To the best of our knowledge, this phenomenon has not been found in recorded drumming in popular music before, when nmetronome was present during the recording, and when no individual drum tracks were available. The LRCs seem to wash away in short time scales, likely due to motor delays studied before in human cognition."

## Notes over these papers

I like the notation and some of the writing style in "Nature and Perception..", at least the way they portray beat detection and other things.

## Issues with focusing on long-range correlations

These papers put all of their effort into measuring how much the rhythms correlate bars later instead of sub-beats later. This doesn't actually say much about rhythm the way I think of it. Inter-beat rhythm can have an instantly good feeling in just a few counts. 4-8 hi hat counts can feel funky and groovy and high quality without any long range correlations.

## Concepts needed for my research

**Autocorrelation** measures the correlation of a signal with a delayed copy of itself. Essentially, it quantifies the similarity between observations of a random variable at different points in time. The analysis of autocorrelation is a mathematical tool for identifying repeating patterns or hidden periodicities within a signal obscured by noise. Autocorrelation is widely used in signal processing, time domain and time series analysis to understand the behavior of data over time.

$$R_{XX}(t_1, t_2) = E\left[X_{t_1}\ \bar{X}_{t_2}\right]$$

Where $E$ is the expected value operator and the bar represents complex conjugation. Expected value being a generaliztion of a weighted average or mean.

Interestingly this autocorrelation function(?) is related to the spectral power density $S_{XX}$ by the Fourier transform

$$S_{XX}(\omega) = \int_{-\infty}^{\infty} R_{XX}(\tau) e^{-i\omega\tau} d\tau$$

Where $\omega = e^{-i2\pi\xi t}$ as in the Fourier transform integrand
Spectral power density is equivalent to frequency analyzer

Paper refers to "lag-1" autocorrelation. From nist.gov section on exploratory data analysis:

Given measurements, $Y_1, Y_2, \ldots, Y_N$ at time $X_1, X_2, \ldots, X_N$, the lag $k$ autocorrelation function is defined as

$$r_k = \frac{\sum_{i=1}^{N-k}(Y_i - \bar{Y})(Y_{i+k} - \bar{Y})}{\sum_{i=1}^{N}(Y_i - \bar{Y})^2}$$

# My spin on the research

## Amplitude

I hypothesize that what makes a drum performance have a perceived human feel has just as much to do with micro amplitude differences as it does micro timing. Could represent as a vector to visually represent the data of what they look like together. Relative amplitude will be interesting to define. Recording env and distortion in recording chain can affect both the relative amplitude detection and the timing onset detection. Higher dynamic range will give a shorter range of time to detect an onset, and will give more bits of information between high/med/low amplitude to be able to tell them apart better. A super compressed or distorted recording will make it tough to calculate the relative amplitudes of the different hits.