Testing auditory neural function using high stimulus repetition rates is limited by the problem of overlap in the evoked responses recorded. Traditionally, stimuli are delivered using uniform or periodic interstimulus intervals (ISI) which, if presented at high repetition rates, produce overlapped response waveforms [v(t)] that can be described as:

$$v(t) = b(t) + b(t + S) + b(t + 2S) + \ldots$$

where b(t) is the transient response and S is the ISI of the continuous, uniform rate stimulus. Under these conditions, the transient response, b(t), cannot be recovered from the recorded v(t).

A unique solution can be found and the transient response b(t) recovered, if the stimuli are delivered at a pseudo-uniform or jittered rate. Under these conditions, a recording of overlapped waveforms can be described as:

$$v(t) = b(t) + b(t + [S +/- J_1]) + b(t + [2S +/- J_2]) + \ldots$$

where S is the mean ISI and J_i is a variable bounded by some maximum jitter around S. Thus we introduce the concepts of a *pseudo periodic stimulus sequence* q(t), and the *special case convolution* to provide a mathematical framework describing the process by which transient waveforms are non-uniformly overlapped. The overlapped auditory evoked responses recorded at high stimulation rates can now be considered as the convolution of the transient response to a single stimulus in the train and the *pseudo periodic stimulus sequence*:

$$v(t) = b(t) * q(t)$$

The convolution is considered to be a special case, as the stimulus sequence q(t) is binary (consisting solely of ones and zeros). The recovery process can then be represented as the deconvolution of the recorded overlapped transients by the *pseudo periodic stimulus sequence*.

$$F(b(t)) = F(v(t)) / F(q(t)$$

Our *pseudo periodic stimulus sequences*, and the averaged responses to them, are circular by virtue of the fact that we use a 100% duty cycle analogue to digital converter. This circularity permits the use of Fourier Analysis. The Fourier Transform has a deconvolution property that greatly simplifies the computations required for recovery, simplifies the understanding of the recovery process, and serves as a useful tool in construction of filter band passes.

At any given mean constant amplitude stimulus rate, our deconvolution operation reveals an impulse-response-like waveform that can be thought of as identically “evoked” by each stimulus in the train. As a range of stimulus rates is explored, this response waveform changes slowly and then precipitously in both amplitude and latency. This clearly reveals that the global system is nonlinear, and that the response to any one rate and its small jitter range is only *locally linear*. Over a full range of rates, these waveform changes serve to characterize the nonlinear system rate response in a compact and visually intuitive manner that contrasts with the more complete but obscure Wiener and Volterra kernal methods of nonlinear system identification using maximum length sequences (MLS). Our data indicates that several (4 – 6) stimuli need to be delivered at the same high rate before the transient changes from that recovered from a slow rate stimulus.

The overlapped recording v(t) has been averaged to reduce background EEG noise, requiring that careful consideration needs be made in choosing the time duration of the stimulus sequence (Sequence Length, SL). The SL determines the averaging interval, thus directly corresponding to the overall duration of a recording session. In addition to averaging, the choice of pseudo periodic sequence also influences the effect of background EEG noise on the recovered waveform. In the presence of noise, the overlapped recording v(t) becomes:

$$v(t) = b(t) * q(t) + n(t)$$

Where n(t) represents the averaged background EEG noise. In the absence of noise, any pseudo periodic stimulus sequence will recover the transient waveform. However, the addition of noise adds an additional requirement that must be considered in considering the stimulus sequence composition. The two aspects of particular importance in the choice of sequences are discussed in this summary. First, because an isochronous stimulus train has a Fourier transform containing zeros, it cannot be used to divide out the sequence impulse train for deconvolution. We therefore use the pseudo periodic stimulus trains whose Fourier coefficients are all greater than one. Where the Fourier coefficients are large, greater reductions in noise will be seen in the recovered waveform. The longer the SL, the easier it is to find sequences with large Fourier coefficients that reduce noise in the division of output transform by sequence transform that accomplishes the deconvolution. Recall, however, that the SL informs the run time for each experimental condition; thus optimization of sequence structure is imperitive. The factors to be considered in choosing a stimulus sequence in addition to specific numerical techniques for finding optimal sequences will be discussed in greater detail in the full presentation.

We have termed the novel analytic methodology described above the WAAD method, or **W**rap **A**round **A**verage **D**econvolution. Using this methodology we are able to recover the mean brain response to individual stimuli delivered at high rates of nearly periodic stimulation. As noted above, these responses show changes in both amplitude and latency as the rate of stimulation increases from 20 – 100 Hz. These novel physiological responses correspond to the psychophysical onset of pitch perception that occurs at repetition rates between 15 and 25 Hz. These data are consistent with a large literature indicating that pitch perception is given by stimulation rate in primate auditory cortex over the repetition rate range of 1-100 Hz. Thus, our technique has allowed discovery of new physiological correlates of known perceptual phenomena.

This work is partially supported by the following awards: NS26209, MH54922, NS36880, RR14002 (DLJ)