

# Software for Mind Control

Ben Pearre

October 7, 2015  
(Rev. -2)

# Outline

## Syllable detector

Goals

Workflow

Results

Current status

## Stimulation

Goals

Tools — hardware

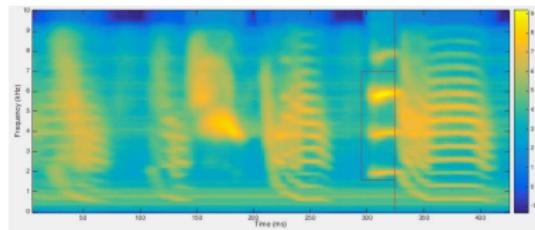
Tools — software

Results

## The Future!

Ideas

# Syllable Detector



## Goals:

- ▶ Detect any point in song?
- ▶ Best accuracy
- ▶ Low latency
- ▶ Low jitter

# Workflow

`zftftb_song_clust.m` — Jeff

Align raw data



`learn_detector.m` — Ben

Find your favourite syllables; train neural network



`nnfft.vi` — Ben

Run the neural network in LabView

## Jeff's song alignment

Install from <https://github.com/jmarkow>:

- ▶ ephys
- ▶ markolab
- ▶ zftftb
- ▶ robofinch

Workflow—using `zftftb_song_clust.m`:

- ▶ Select template syllable
- ▶ Cluster

Align  $\gtrapprox$  500 songs.

**Input:** Raw recordings

**Output:** A Matlab file of aligned songs

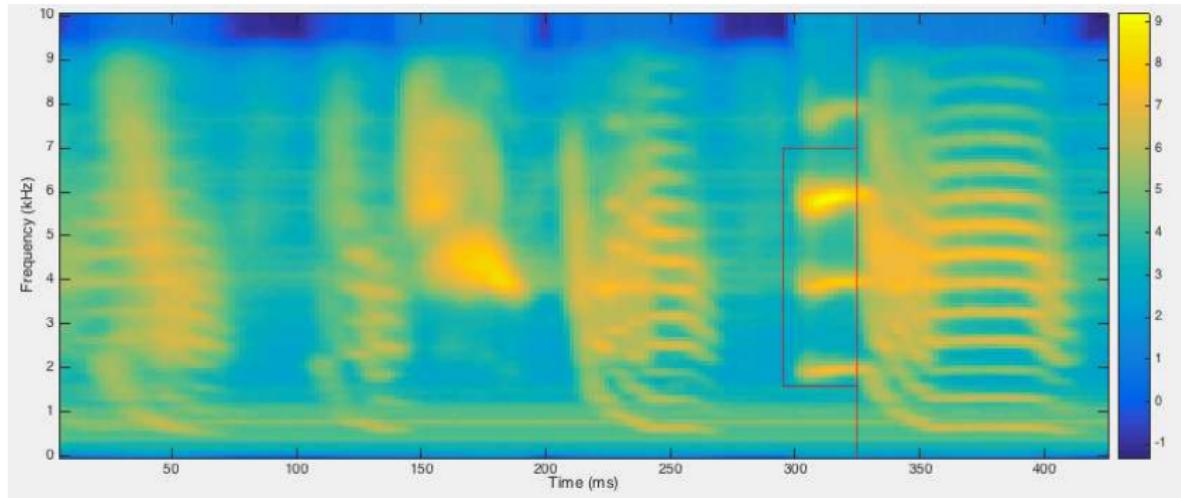
## Ben's song detection

Install from <https://github.com/bwpearre>:

- ▶ birds

Load `birds/align/learn_detector.m`:

## learn\_detector.m (Matlab)

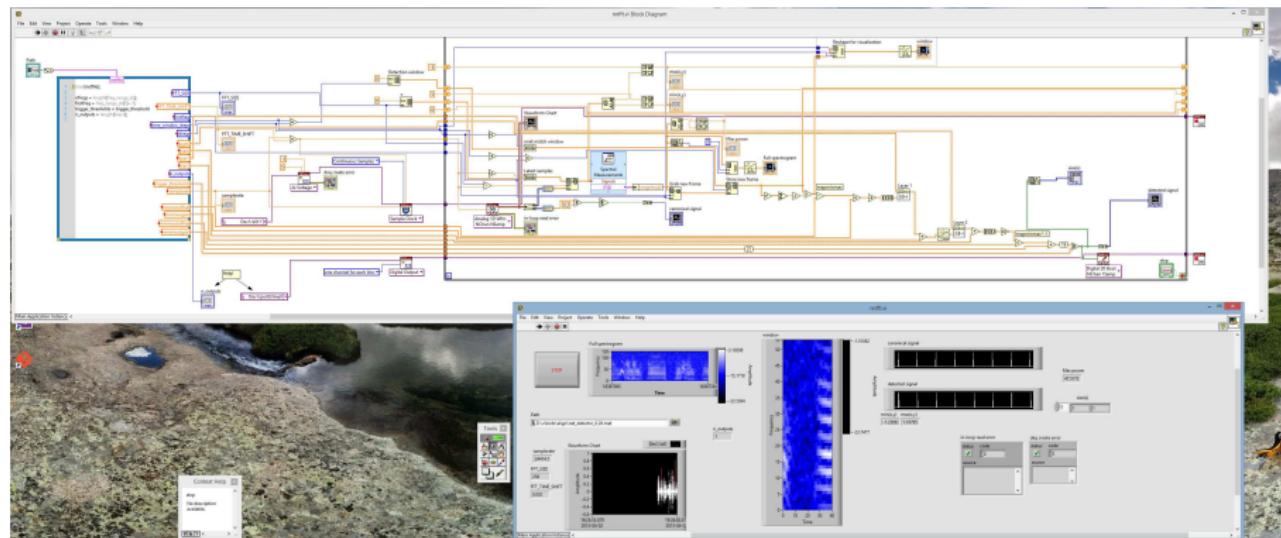


Input: Aligned songs from `zftftb_song_clust.m`

Output:

- ▶ neural network file
- ▶ audio testing file

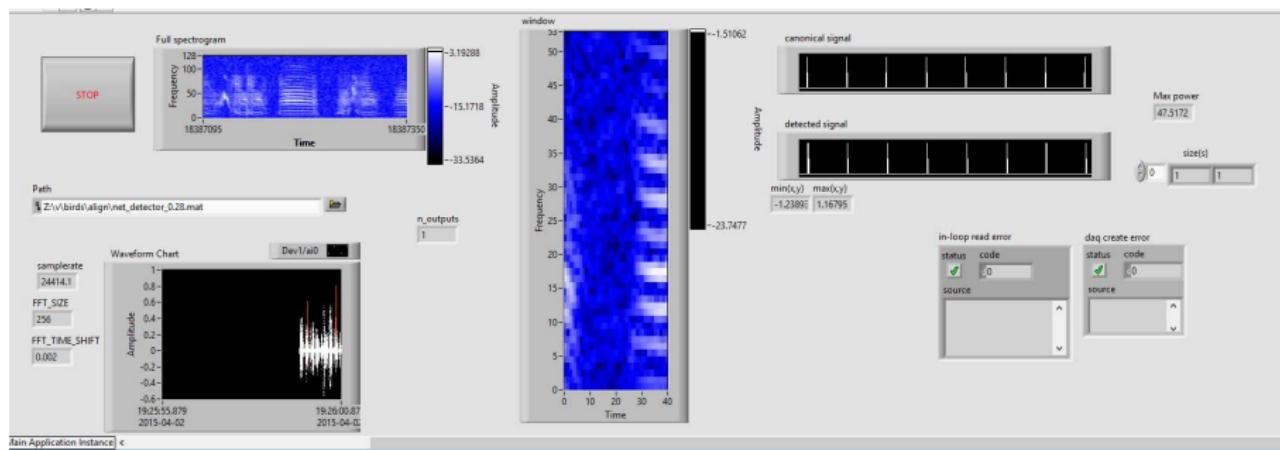
## nnfft.vi (LabView)



Input: Neural network file...

Output: TTL pulses etc...

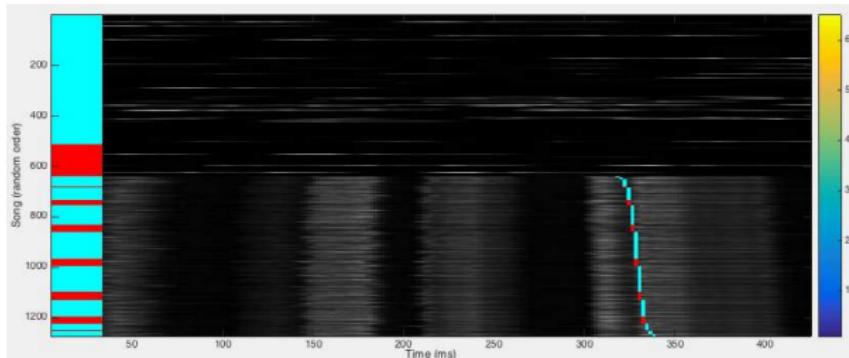
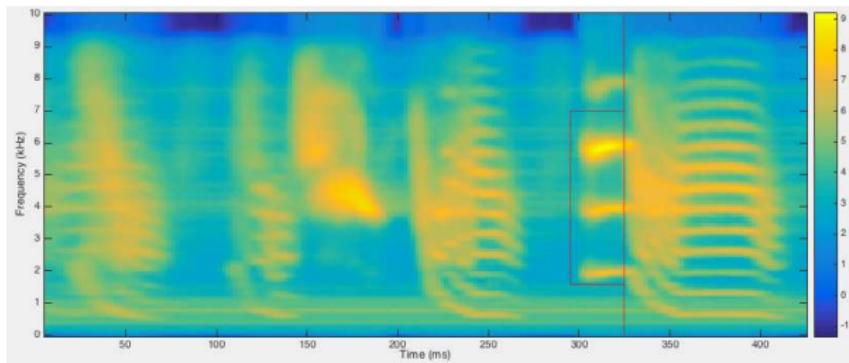
## nnfft.vi (LabView)



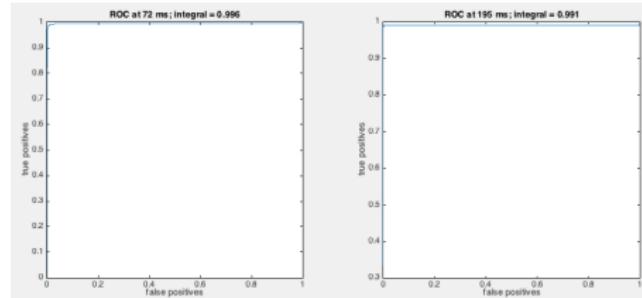
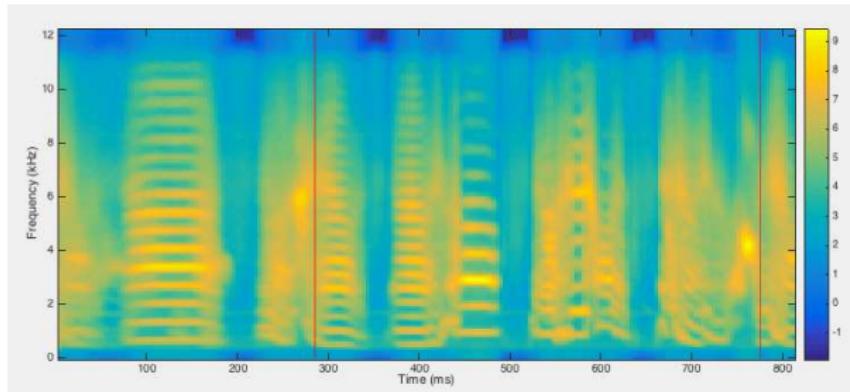
Input: Neural network file...

Output: TTL pulses etc...

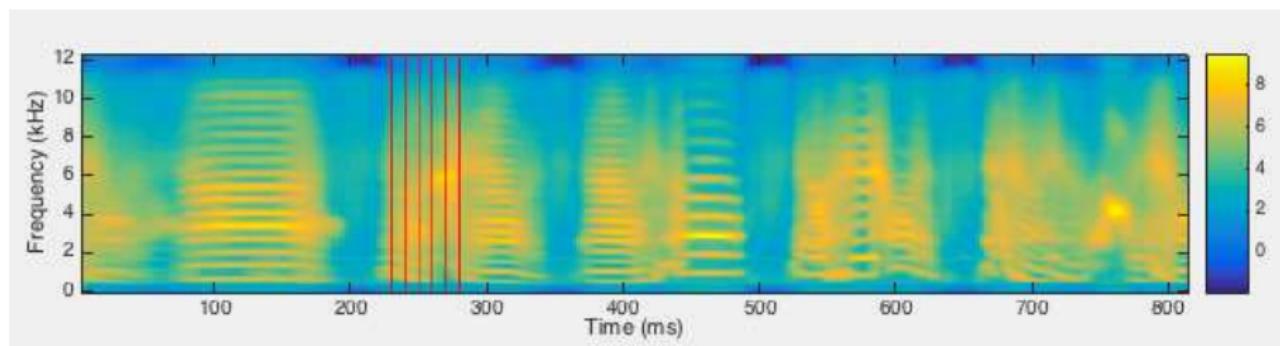
# Detection



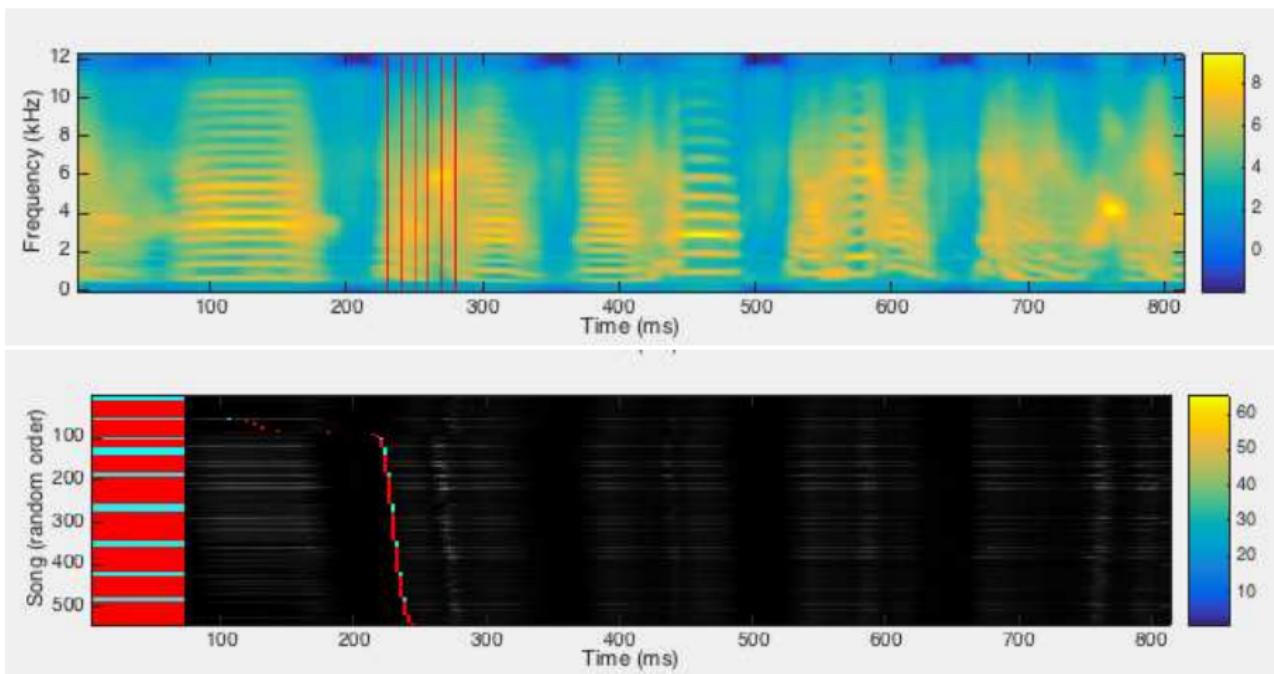
# Detection



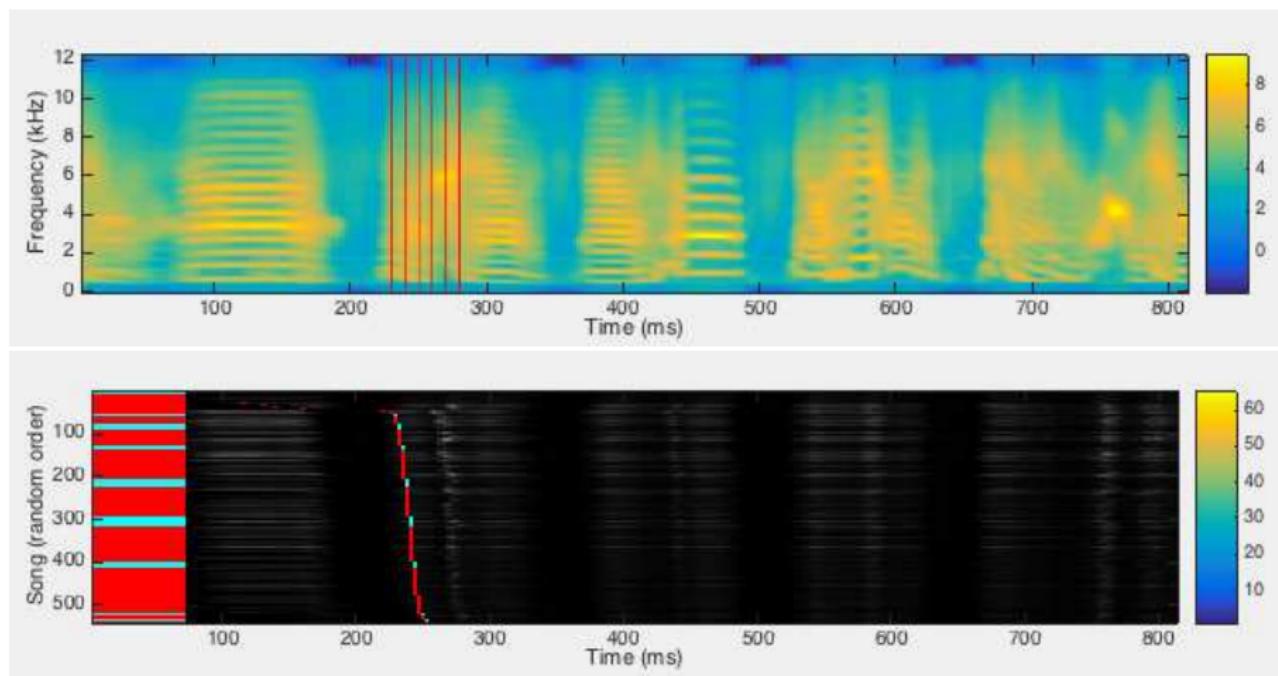
# Detection



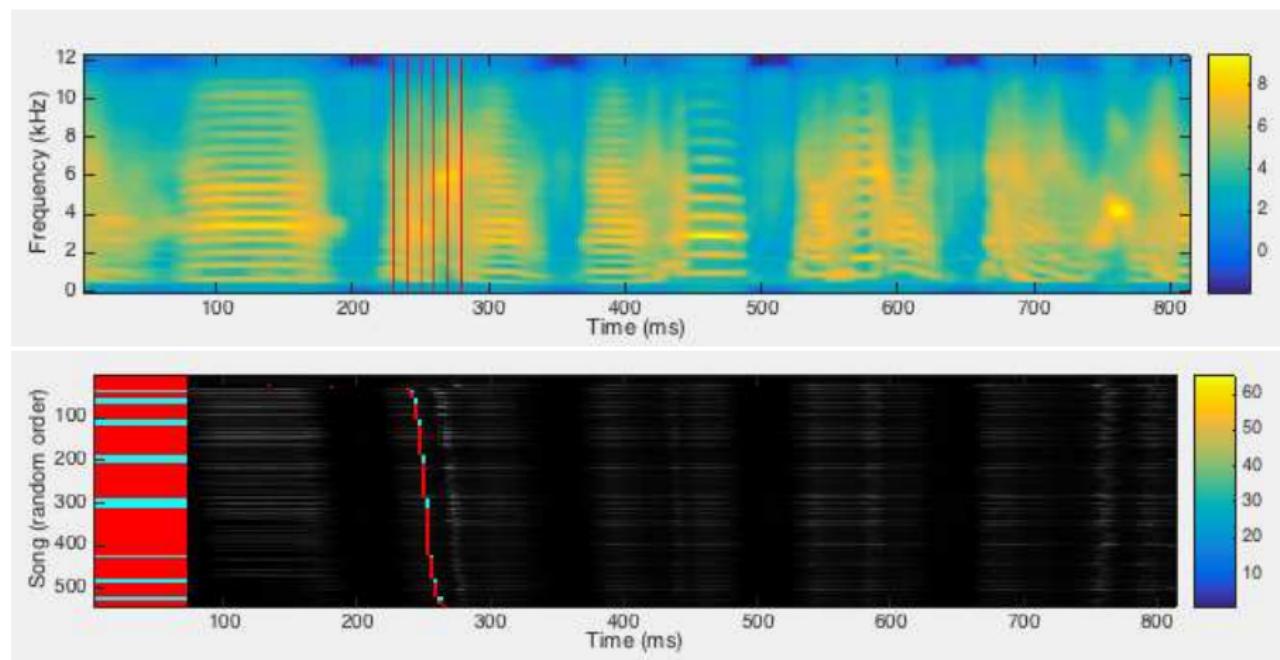
# Detection



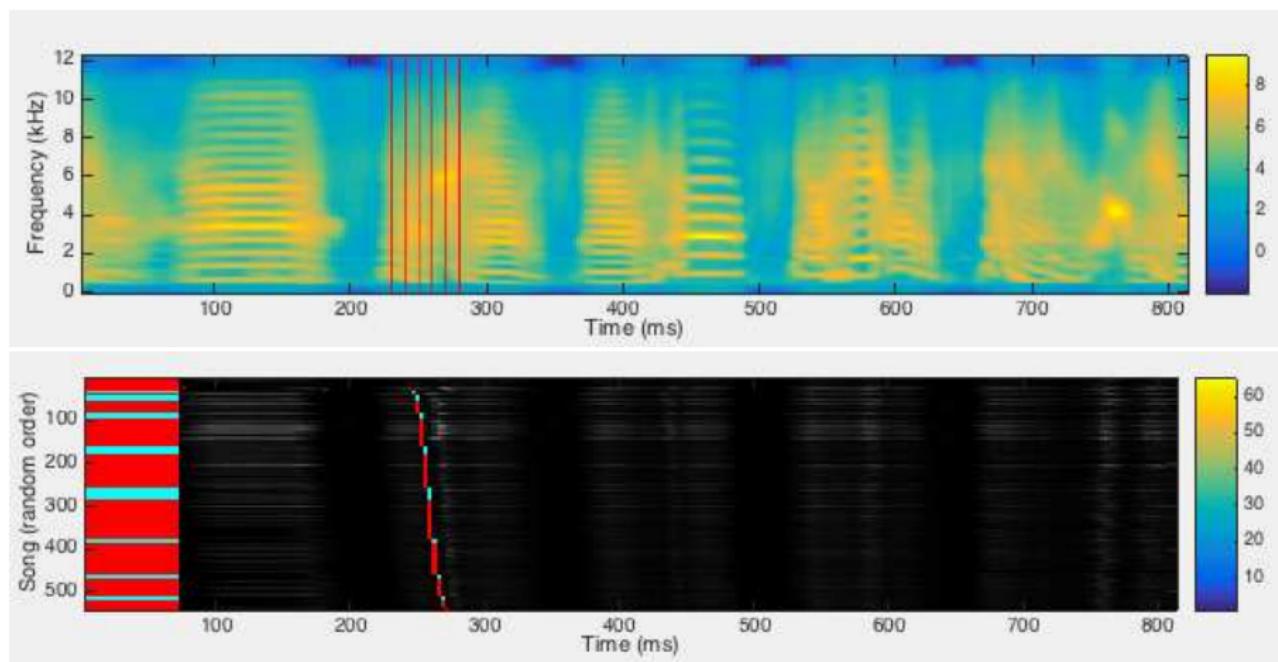
# Detection



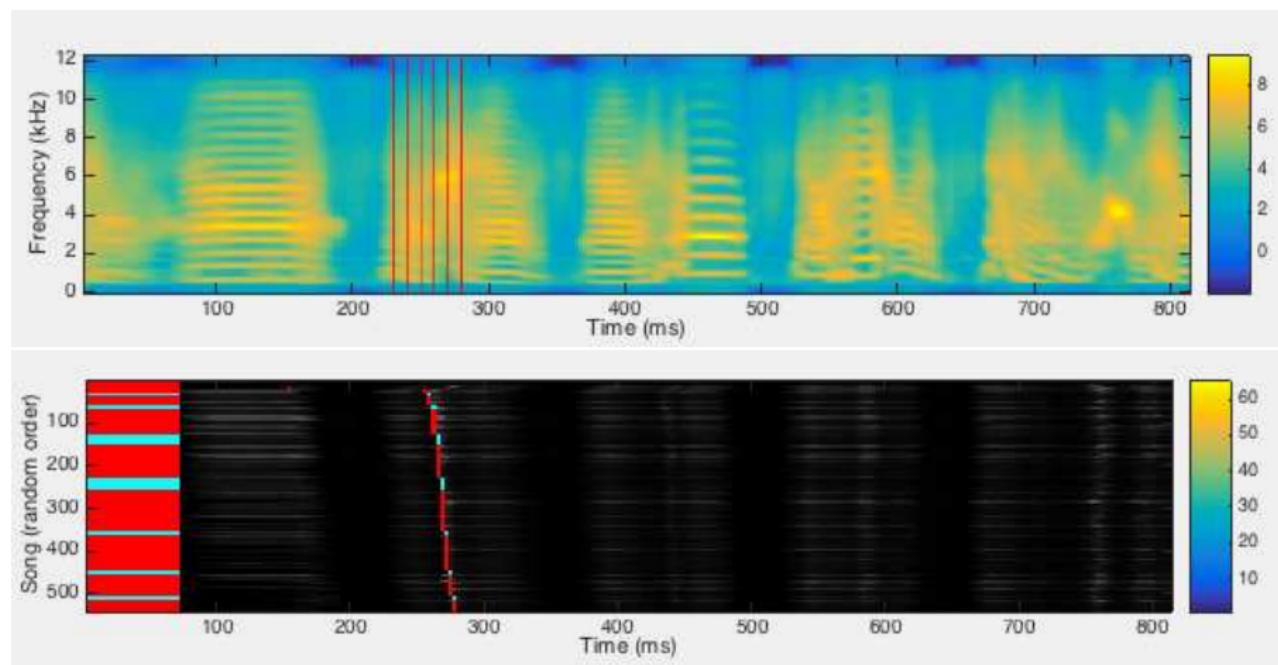
# Detection



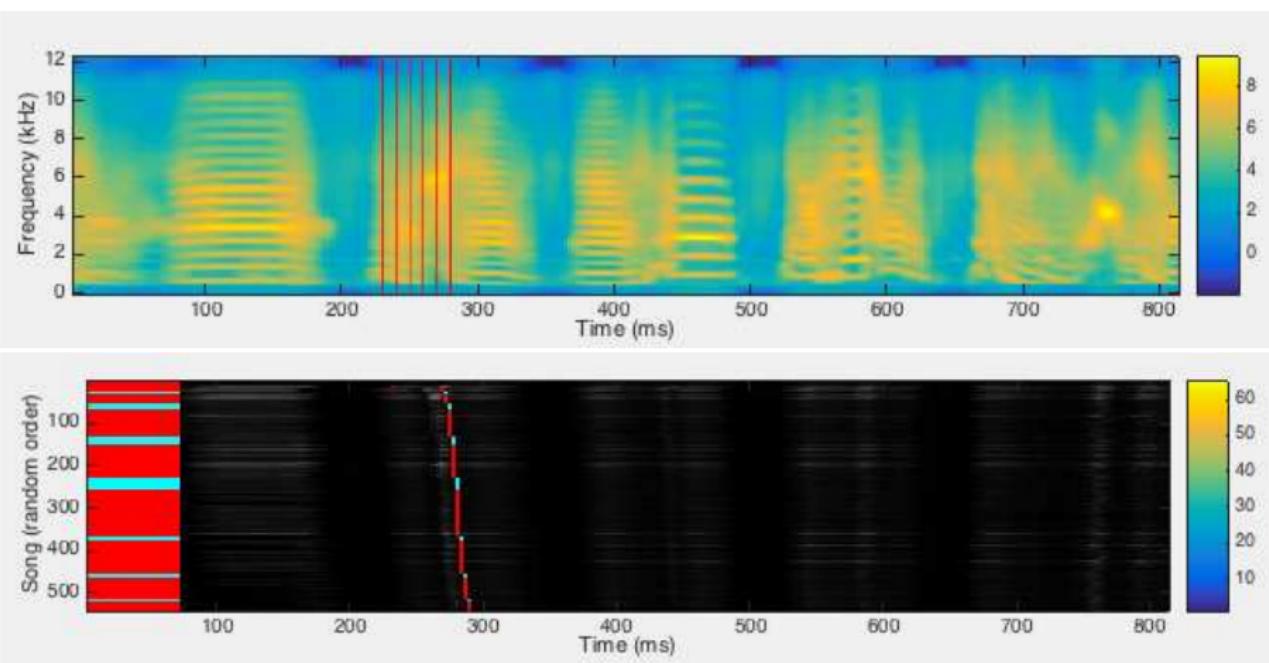
# Detection



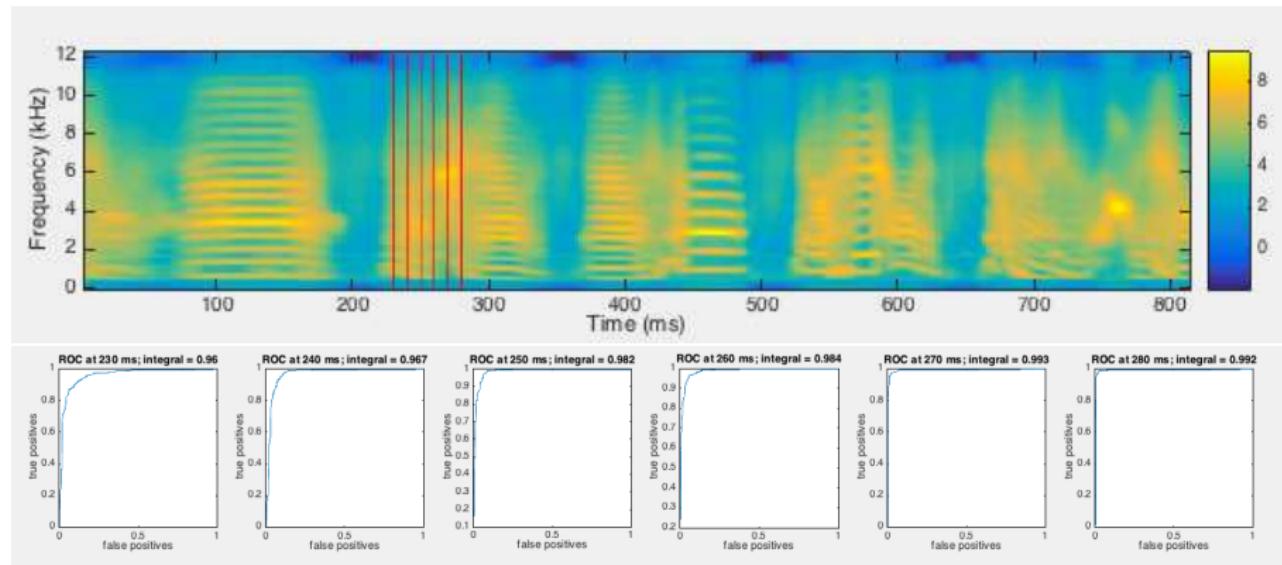
# Detection



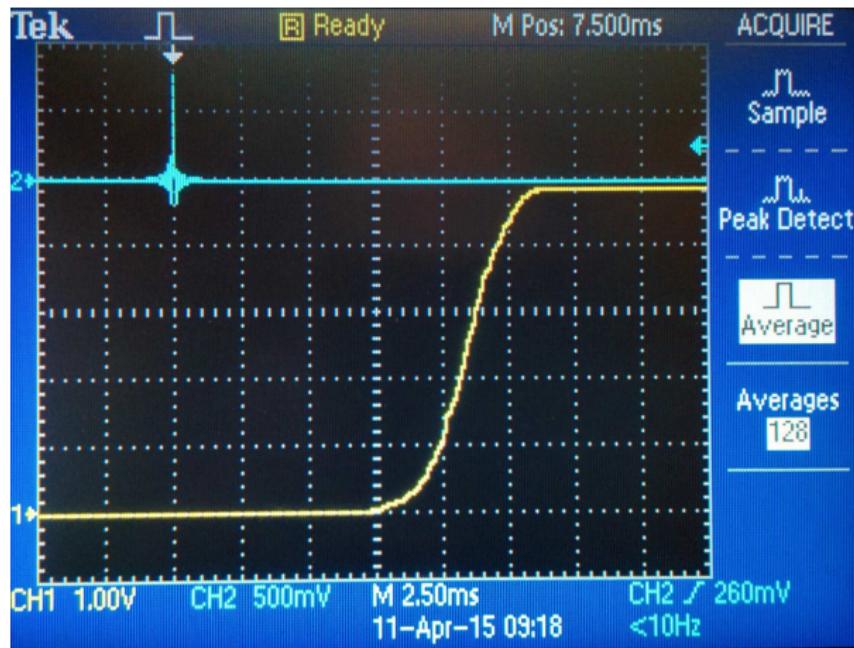
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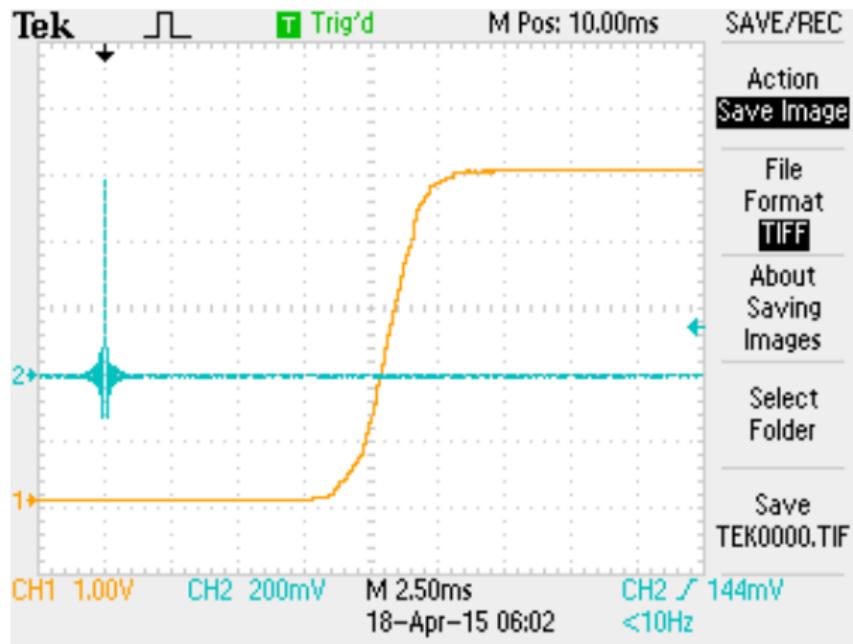
# Detection



## Testing: timing



## Testing: timing



## Current status

- ▶ Matlab has high accuracy!
- ▶ Labview: somewhat lower accuracy. Bug?
- ▶ Inferior song detector
- ▶ Nathan?

# Goals

- ▶ Modify neural signals
  - ▶ CNS
  - ▶ Peripheral — Win!
- ▶ Demonstrate chronically implanted electrodes
- ▶ Optimise stimulation parameters
- ▶ Learn control policies to elicit desired behaviours

# Electrodes

Chronic high-count low-impedance . . .

- ▶ Carbon fibres
- ▶ Carbon nanotubes
- ▶ Silicon carbide
- ▶ Optical . . . ?

## Plexon stimulator

- ▶ 16 channels
- ▶ Current-controlled
- ▶ Externally triggered
- ▶ Arbitrary pulse waveforms
- ▶ 30 nA resolution, possibly...
- ▶ Matlab API
- ▶ Reprogramming time  $\simeq$  0.05s/channel (?)

# Recording amplifiers

## Intan

- ▶ ≥ 16 channels
- ▶ Easy impedance measurements
- ▶ Low noise
- ▶ *Very poor blanking!*
  - ▶ artifacts at > 3ms

## A M Systems

- ▶ 2 or 4 channels per amp
  - ▶ Connectivity?
- ▶ Few artifacts
- ▶ Difficult to do impedance measurements
- ▶ Headstages need to be built

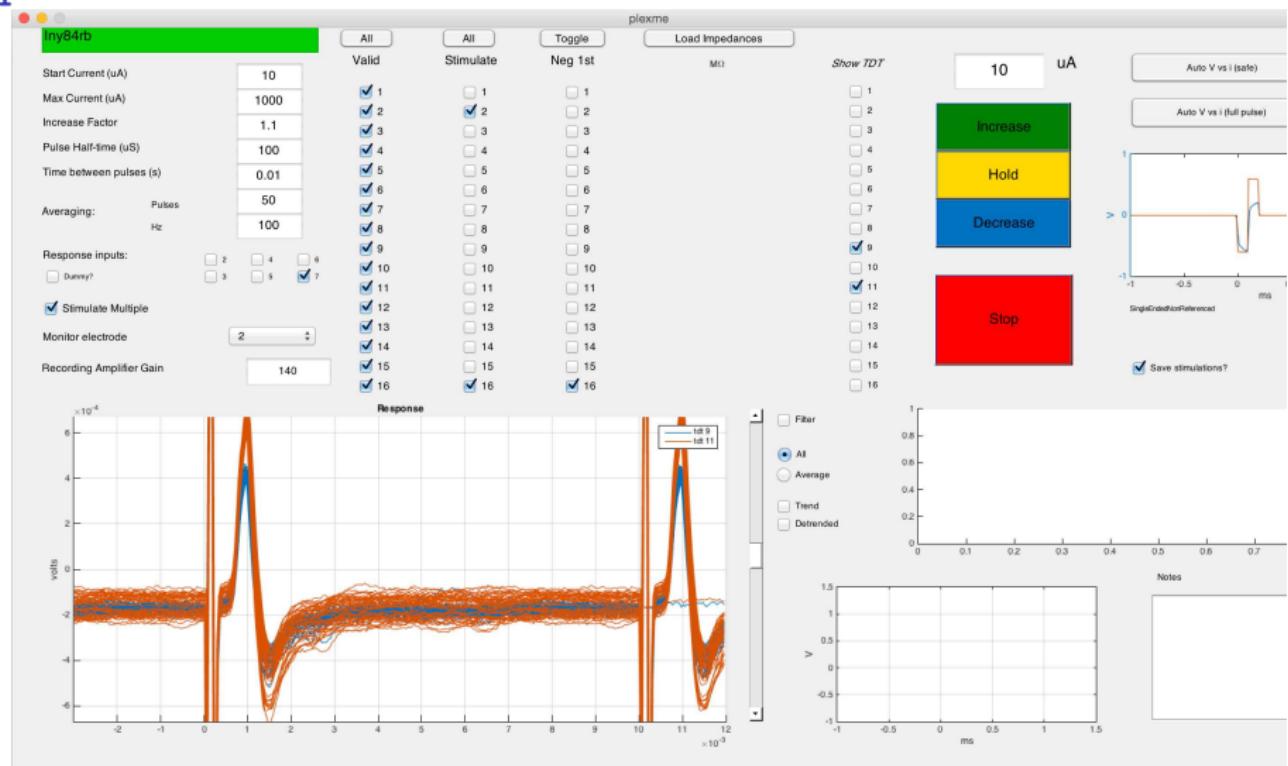
## TDT

- ▶ ≥ 16 channels
- ▶ No impedance measurements
- ▶ Low noise
- ▶ Few artifacts
- ▶ Talks to Matlab
- ▶ Quirky. Buggy.
- ▶ ... oh, and it's also a DSP!

Syllable detector  
Stimulation  
The Future!

Goals  
Tools — hardware  
Tools — software  
Results

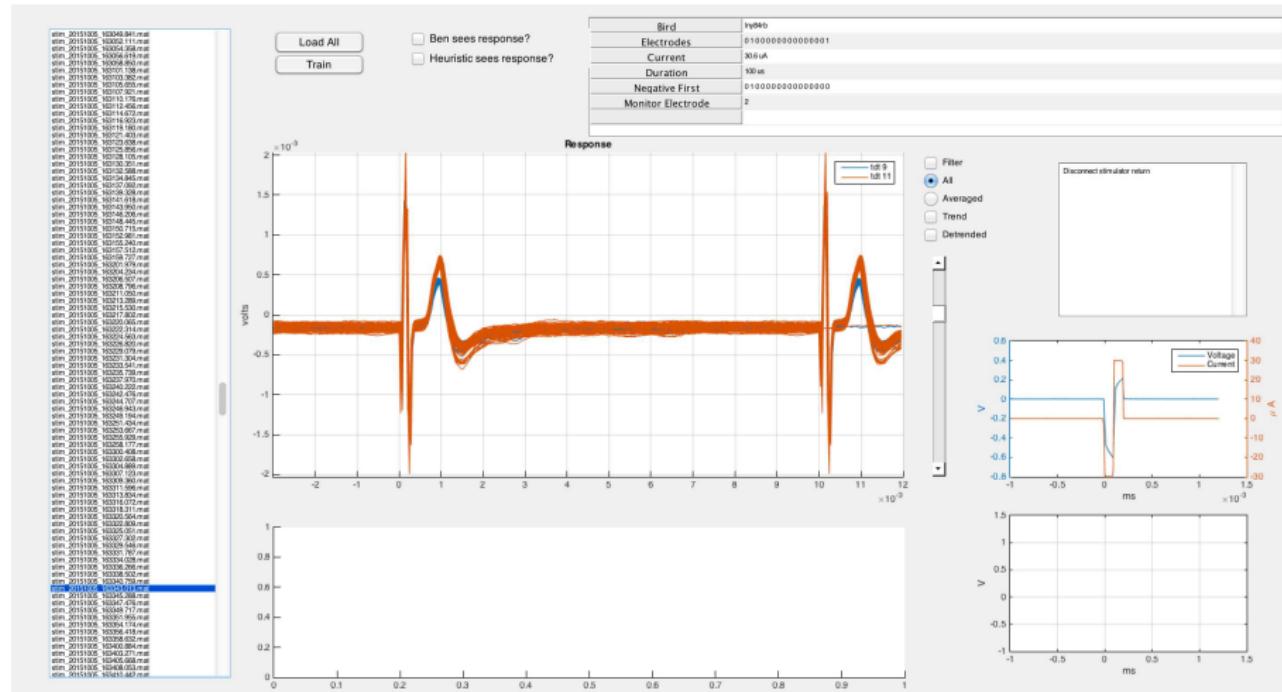
plexme



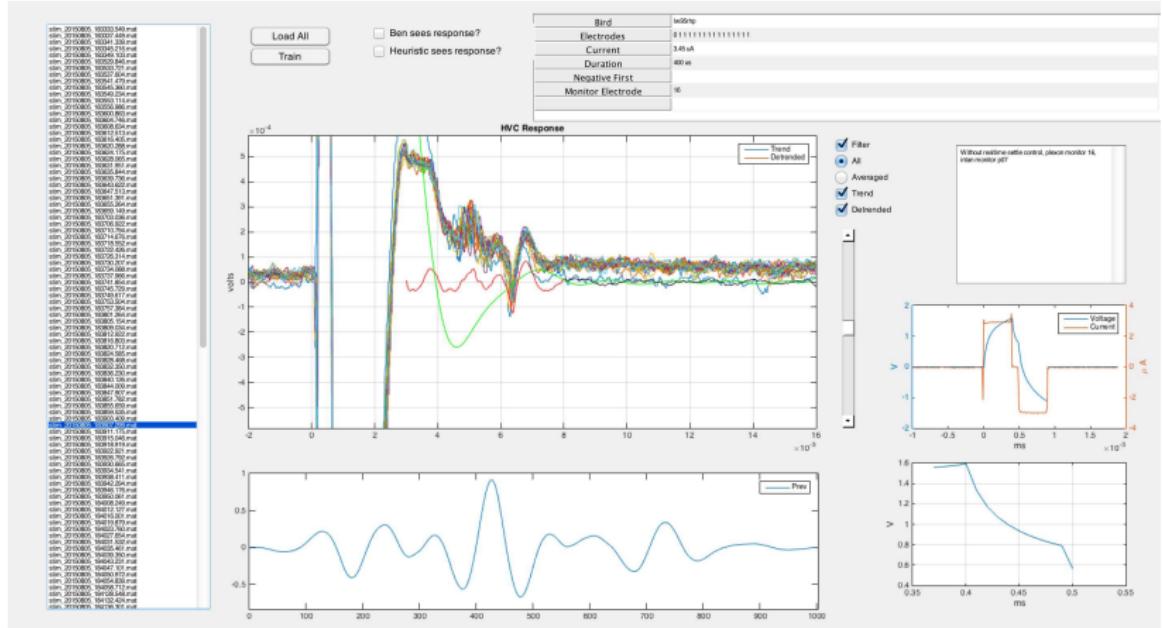
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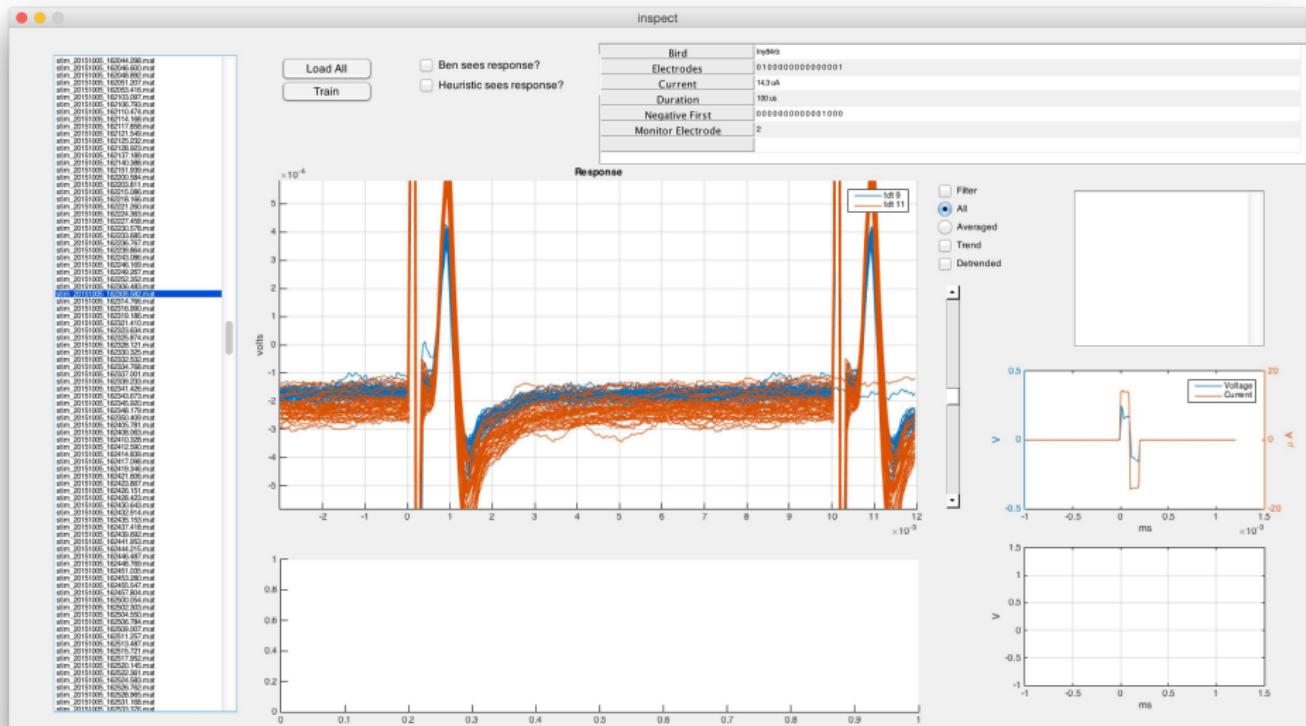
inspect



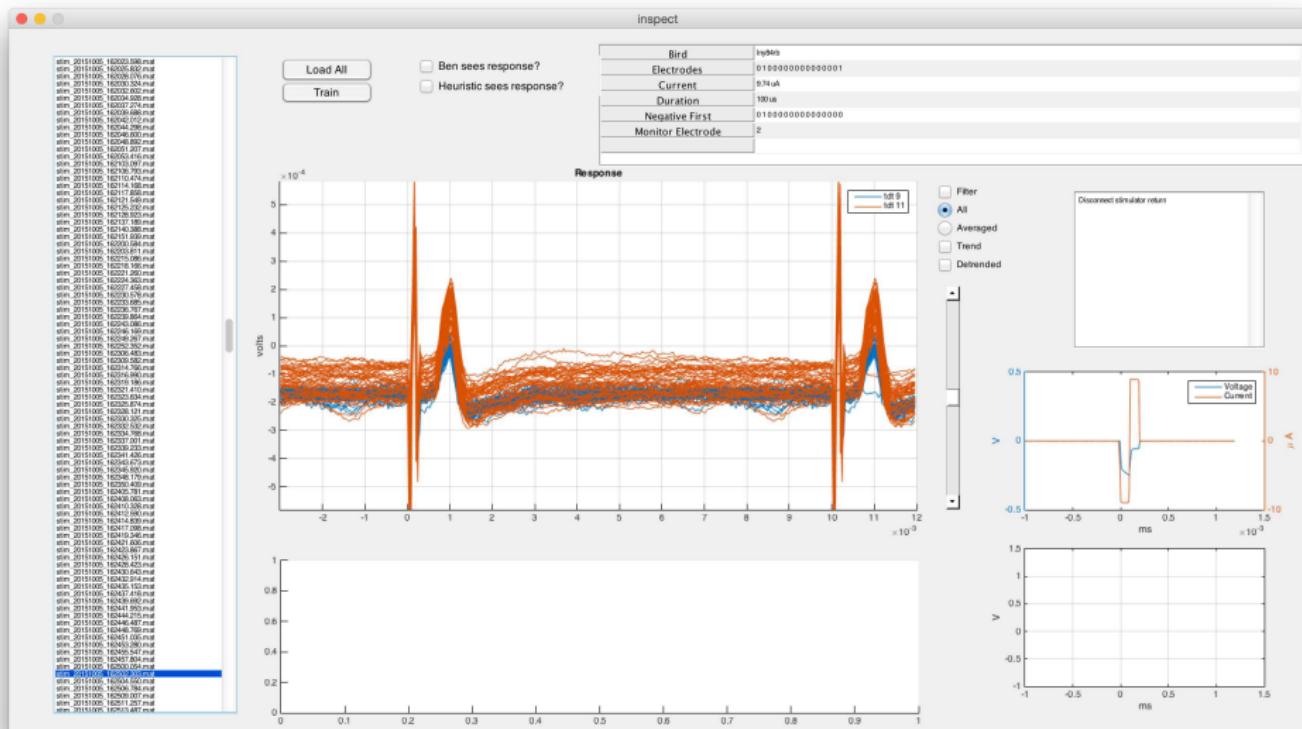
# Antedromic HVC $\leftarrow$ X response (Intan)



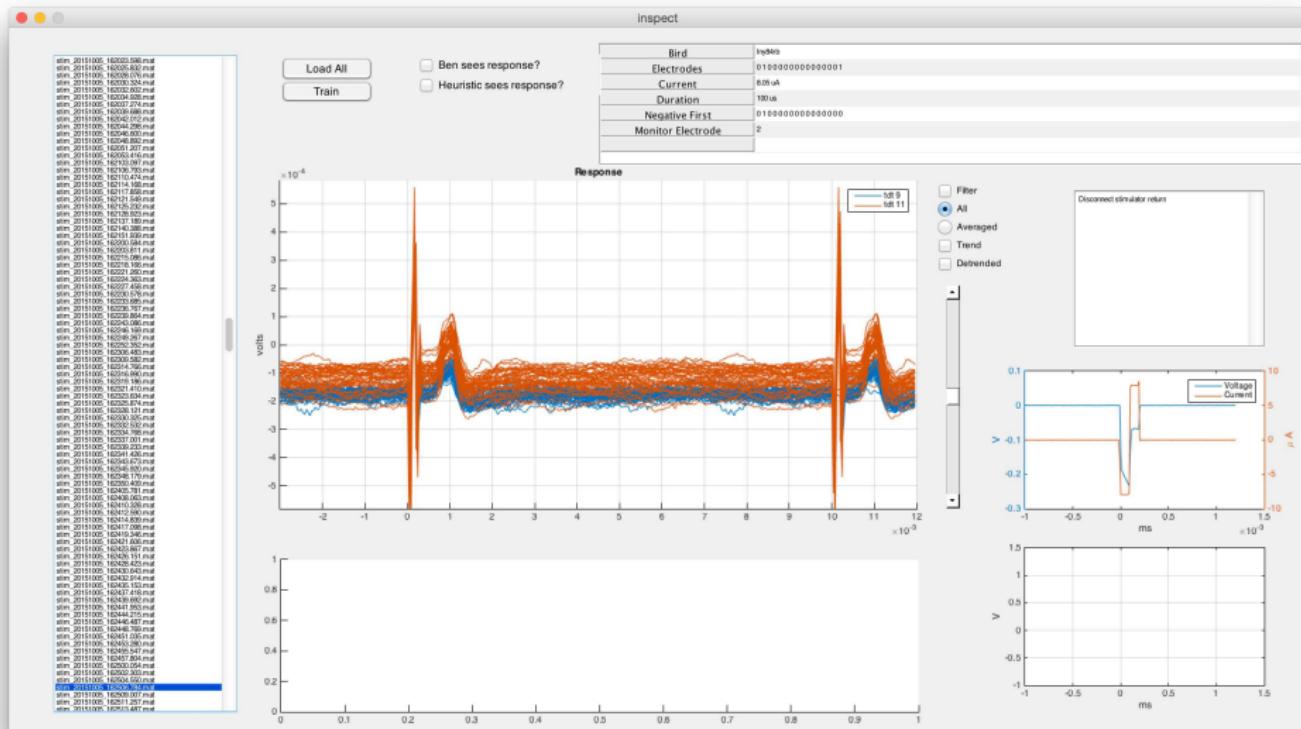
# Finding a response threshold



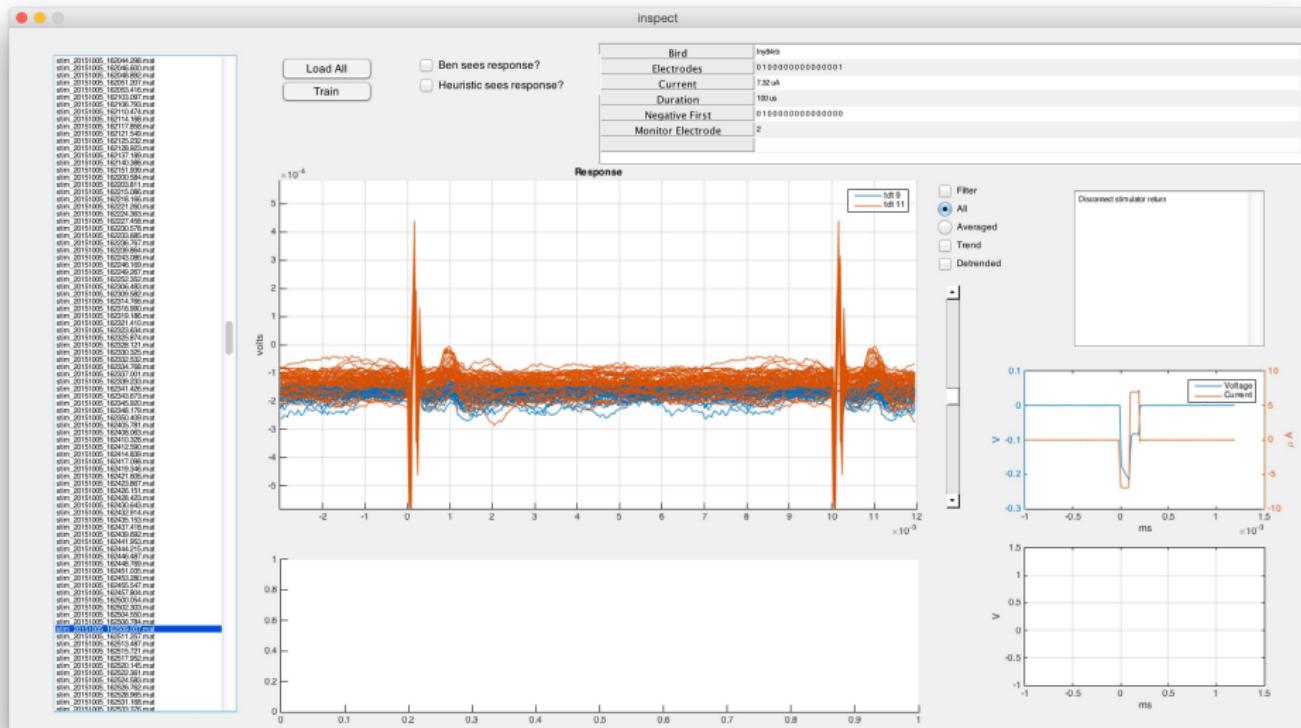
# Finding a response threshold



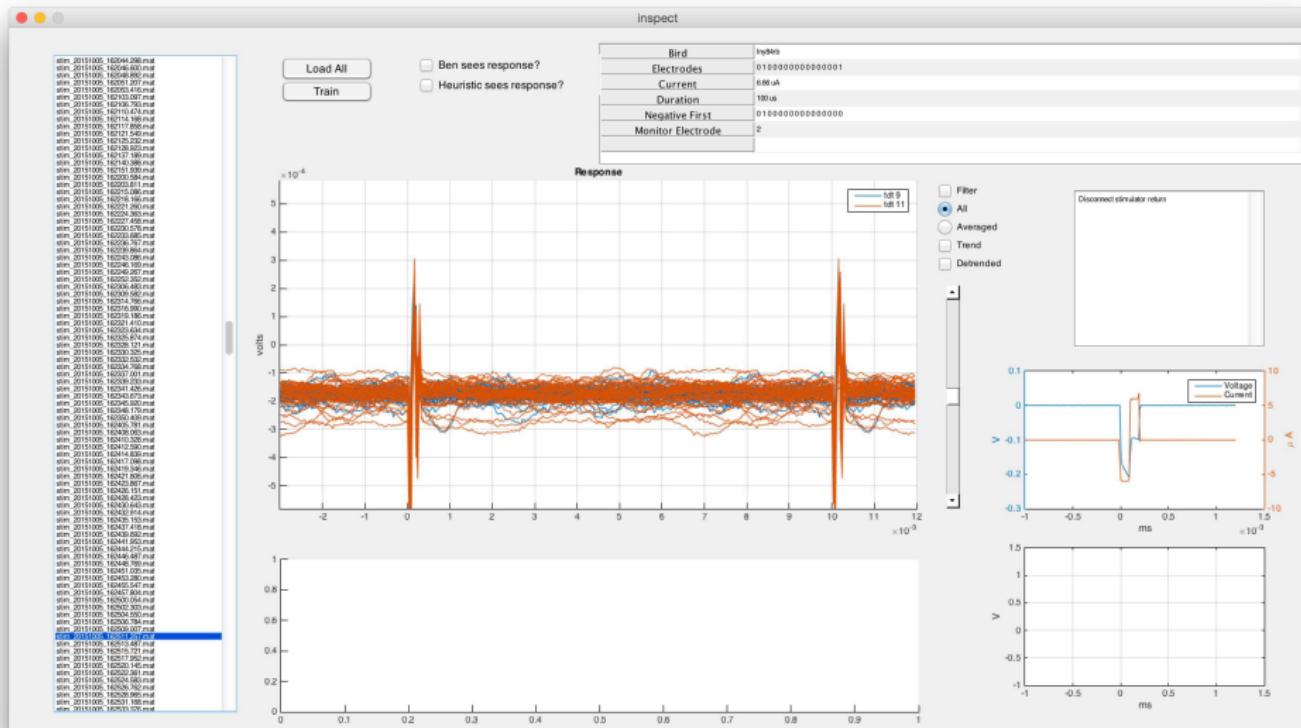
# Finding a response threshold



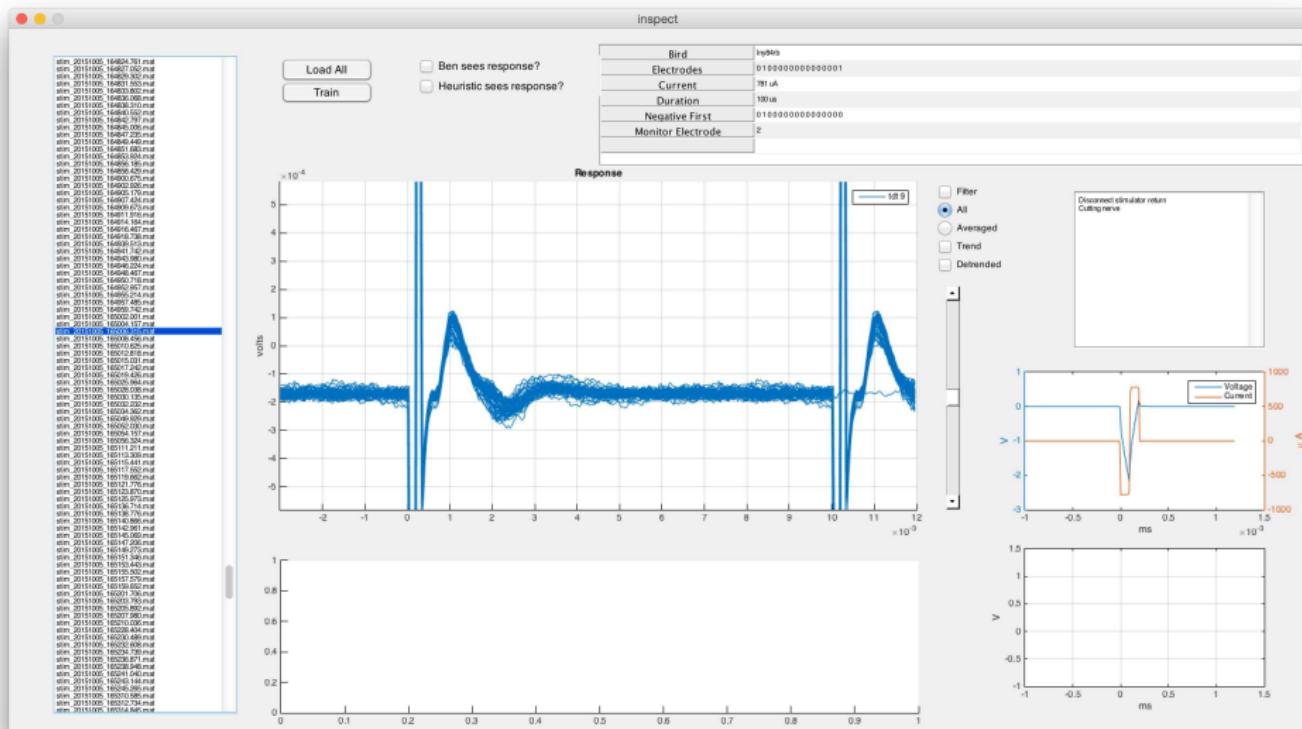
# Finding a response threshold



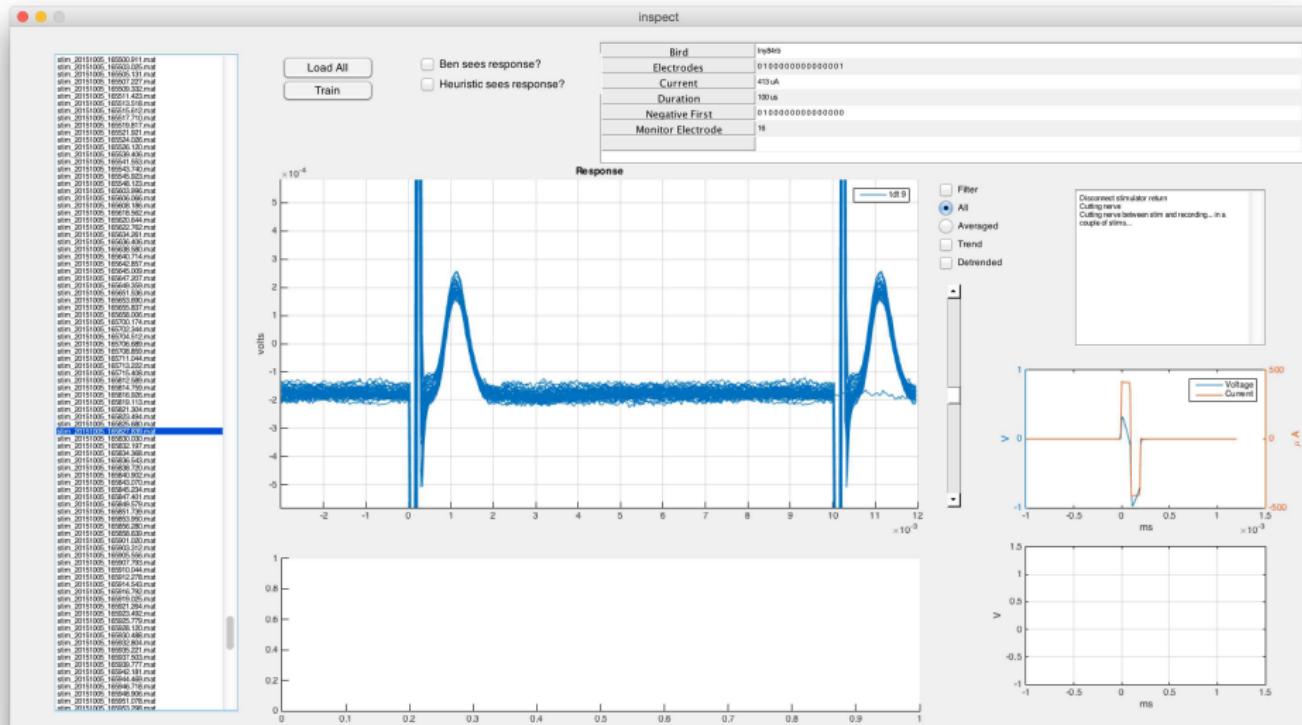
# Finding a response threshold



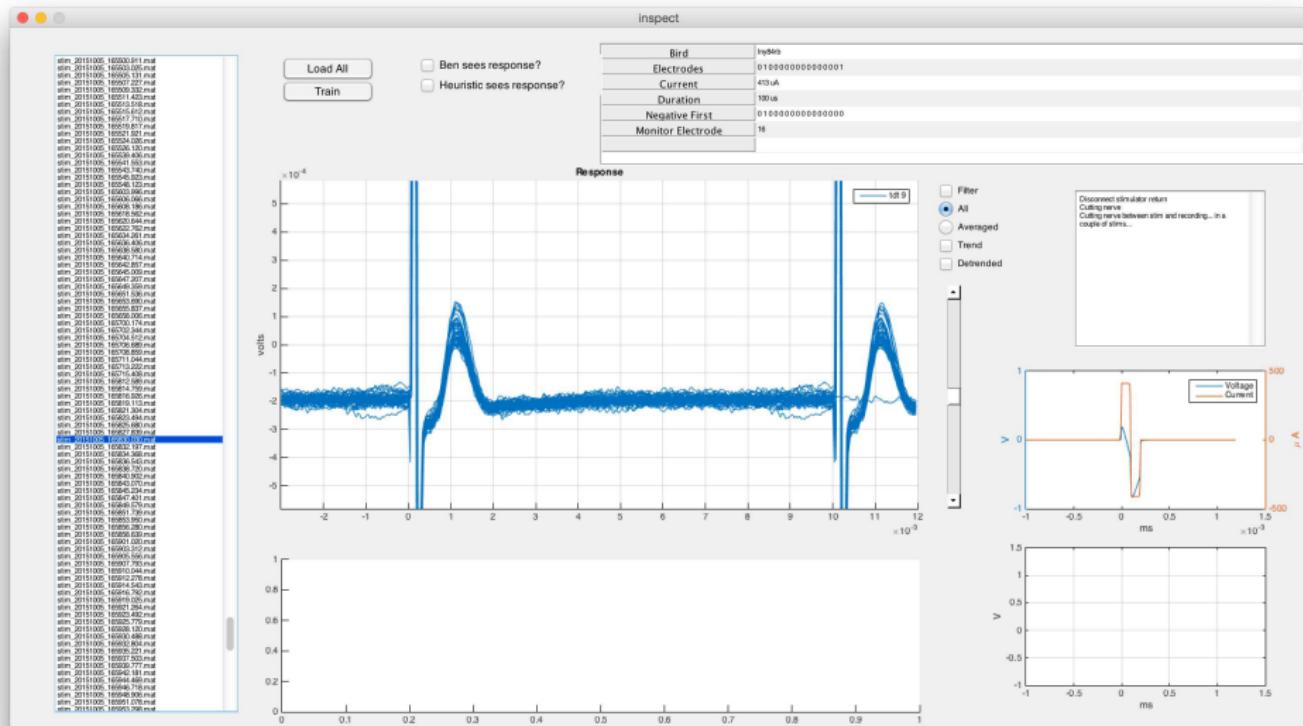
# Nerve is cut... somewhere...?



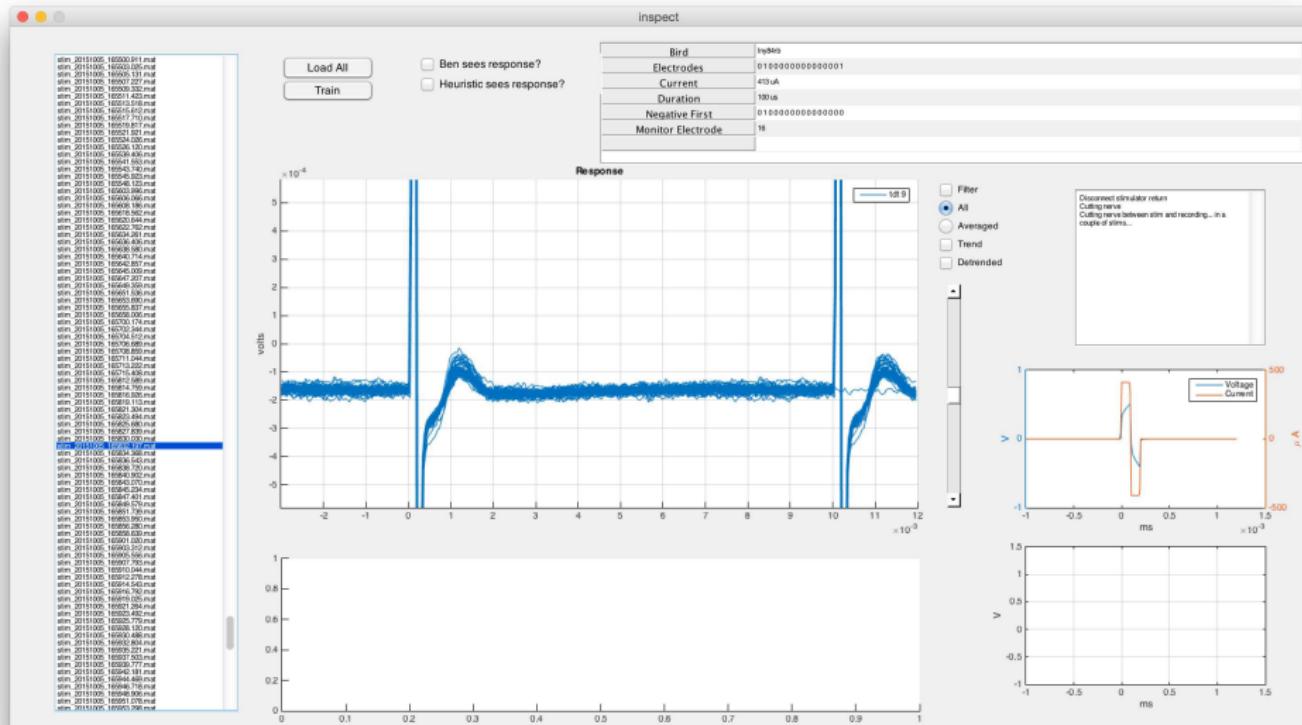
# Cutting nerve between stim and recording electrodes



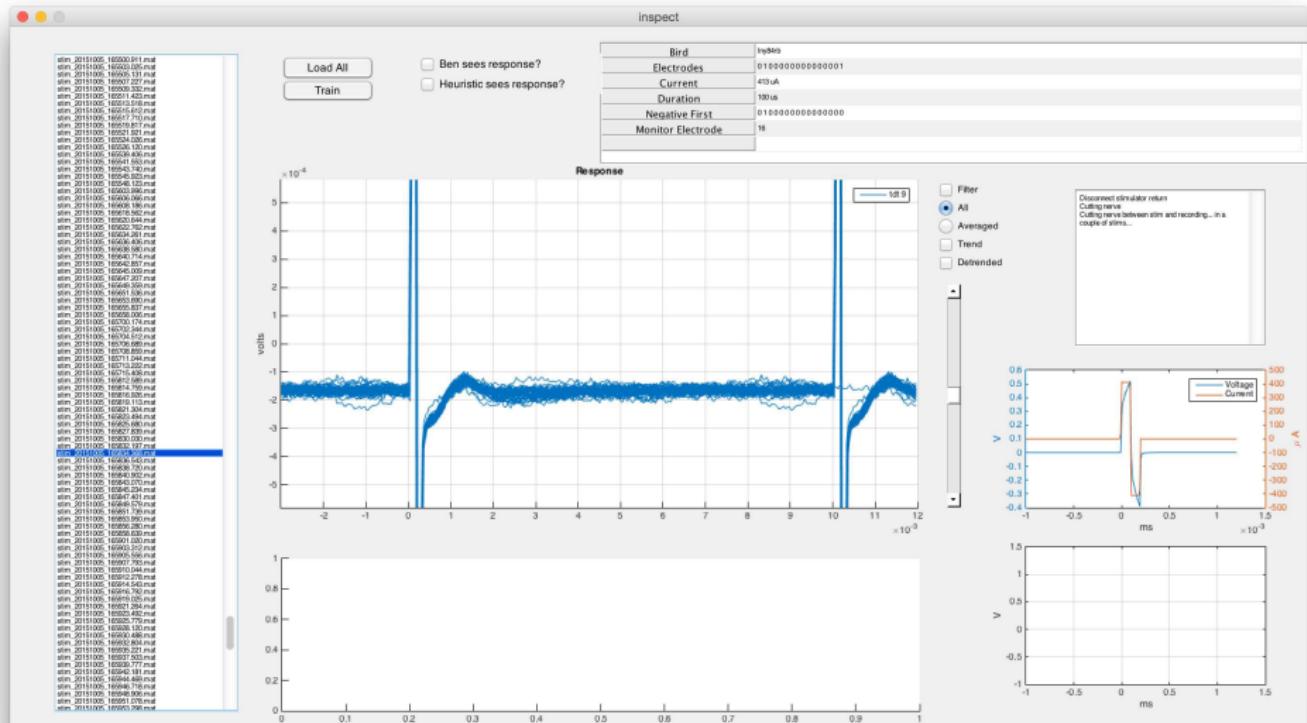
# Cutting nerve between stim and recording electrodes



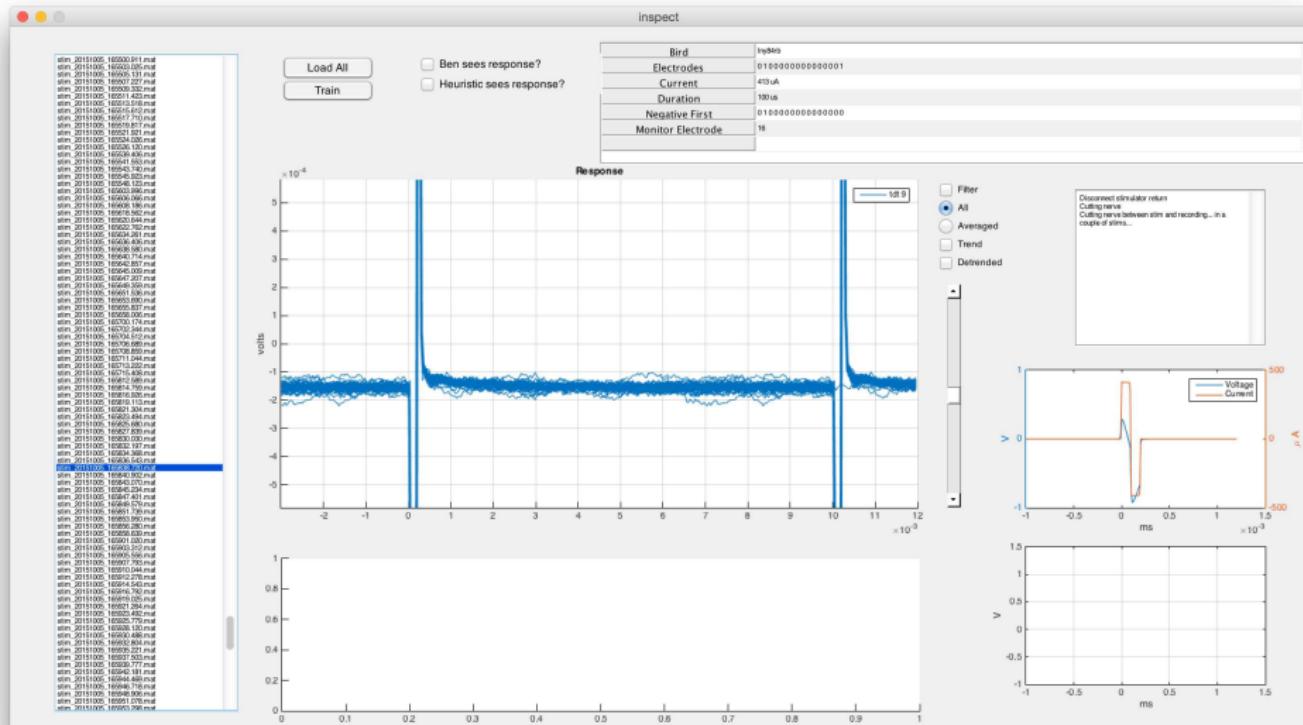
# Cutting nerve between stim and recording electrodes



# Cutting nerve between stim and recording electrodes



# Cutting nerve between stim and recording electrodes



## Stimulation optimisation

Criteria?

- ▶ Minimise voltage
- ▶ See response (binary?)
- ▶ Response separation
- ▶ Directed change to song
  - ▶ Acute
  - ▶ Chronic

Policy outputs?

- ▶ Square pulse width
- ▶ Arbitrary pulse shape
- ▶ Pulse train timing
- ▶ Current steering
- ▶ Channel timing

Policy inputs?

- ▶ Vocalisation
- ▶ Other motor output?
- ▶ Neural activity

## To do:

- ▶ Choose design
- ▶ Implement appropriate learning algorithm(s?)
- ▶ Detect neural response (spike)