Time-scale invariant recognition of a communication signal by a bursting neuron.

Allegro con brio

Andante maestoso
Time-scale invariant recognition of a communication signal by a bursting neuron

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Problems of temporal pattern recognition

Temporal order: 1 2 3 4

Neural networks:
- delay lines and/or memory kernels
- template matching, i.e. integration over space


And biological systems?
see also the poster by J. Hass et al.: Dynamic adaptation in decoding temporal information
Part I: Talk outline

• Burst encoding of stimulus features

• A neuronal circuit for burst encoding

• From burst encoding to time-scale invariant decoding

• Relation to female grasshopper‘s behavior
The grasshopper’s auditory system

What are the functions of the auditory system?

What are the computations for song recognition?

Stimulus and neuronal response

Sound pressure wave

Amplitude - modulation signal

Enlargement, stimulus features

Neuronal (AN12) spike train
Do bursts encode something?
Classification by bursts

Spike count within bursts is sufficient to distinguish mating songs
What is encoded in bursts?
Higher intraburst spike count is related to deeper and longer pauses in the preceding stimulus.
What is *in* the spike count?


Spike count is only weakly correlated to pause-independent parameters.
Spike count encodes pause duration

Pause duration is significantly correlated with the spike count within bursts

Correlation can be fitted by a straight line through the origin

\[ p < 0.0001 \]
Spike count encodes pause duration

In artificial model songs, pause duration and spike count are correlated, too.
How could the encoding of pause duration be implemented?
1) Stimulus processed by adapting receptor neurons (high-pass)
2) Separated into 2 parallel neurons, excitatory & inhibitory
3) Inhibitory neuron low-pass filters receptor signal
4) Added to drive integrate & fire AN12 neuron
Model quality

Model spike train is fitted to the stimulus-driven spike trains:

![Graph showing model spike train compared to stimulus and AN12 response.](image-url)
Model response

The model has a similar burst triggered average and ...

...reproduces the relation between pause-duration and spike-count

Fast excitation and slow inhibition models neural response & pause encoding
Can this pause encoding be related to time-scale invariant decoding?
Time-scale invariance

What is time-scale invariance?
Temporal sequences, that are stretched or compressed versions of each other have to be classified as equal.

"DADADADAMM"

"DDAADDAADDAADDAAMMMM"

Time-scale invariance in the grasshopper:
The female grasshopper still identifies the correct male song when syllables and pauses are stretched with the same factor.
**Time-scale invariance**

What is the obvious strategy?
Calculate the ratio between period (syllable + pause) and pause.

\[
\frac{\text{Period duration}}{\text{Pause duration}} = \frac{\text{Interburst Interval}}{\text{Spike count within burst}}
\]

But a division is rather difficult for neurons and memory is needed...
There might be a way around.

Decoding the neuronal response

Take a long but constant integration window: Total spike count of the AN12 neuron is invariant to signal time-scaling!
Decoding the neuronal response

Model prediction

Experimental data
Spike count invariant of syllable repetition rate
Can we model the female grasshopper's behavior?
Invariance to ratio sufficient?

What is with very long scalings?
What kind of mechanism filters medium spike count?
A behavioral model

The neuronal model circuit

Model: a set of parallel feature detectors integrates sign stimuli. A logical AND-wiring makes the binary decision.
A behavioral model

![Diagram showing behavioral response and thresholds](image-url)
Neurons that integrate and count?


A prediction for behavioral experiments

A: 80/4

B: 54/30

C: 67/17

D: 80/4
   + 54/30
Conclusions

1) Bursts multiplex information

2) Model for AN12

3) Time-scale invariant decoding

4) Parallel feature detectors explain behavioral response