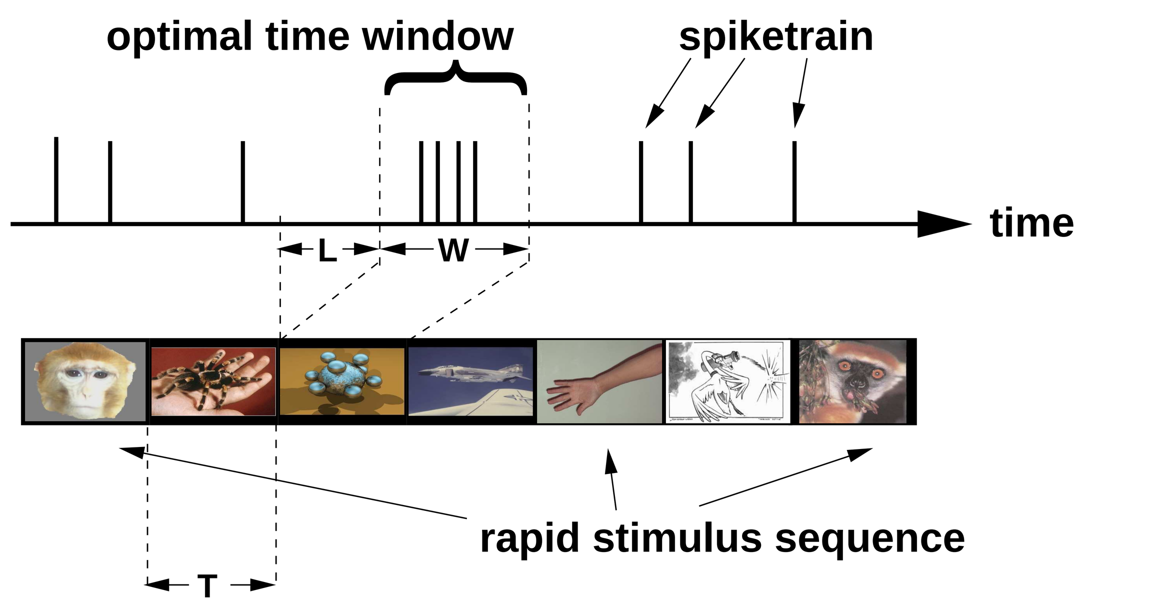
Rapid presentation is efficient for testing visual neurons (area STSa): information rate peaks in the interval [9,24] stimuli/s

Dominik Endres and Peter Földiák
School of Psychology, University of St. Andrews, KY16 9JP, UK
{dme2,pf2}@st-andrews.ac.uk

Objective

We analyse signals recorded from single high level visual cortical neurons (area STSa) of macaque monkeys. Traditionally, individual stimuli were presented well isolated in time allowing easy separation of the responses. The recently developed methods of applying **Rapid Serial Visual Presentation (RSVP)** to single-cell neurophysiological experiments [1, 2] allow a more efficient use of the limited experimental time. We investigate which presentation durations are optimal w.r.t. the information gained about the neurons' selectivities.



T: presentation duration
L: latency, W: response window duration

Stimuli: complex images

Natural photos, isolated faces, cartoons.

Presentation duration T: 14ms - 222ms per stimulus, no gaps

Experimental details in [1, 3, 4, 2]

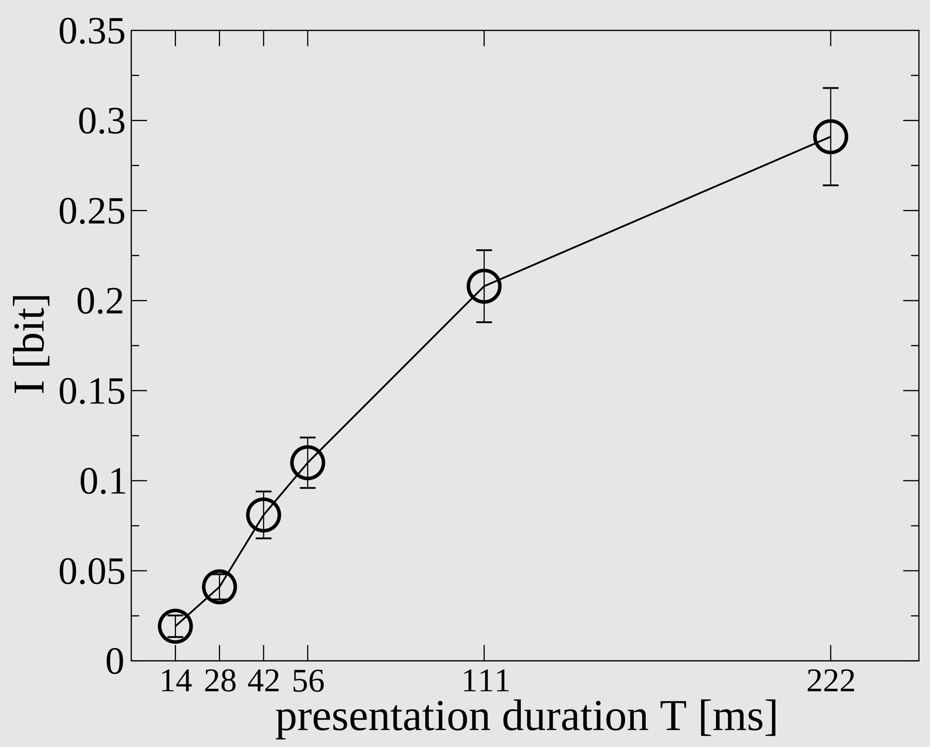
Tasks

1. Find the time window of duration that contains the response to a given stimulus. We do this as detailed in [5].
2. Use this response to compute the **mutual information I** between stimulus label and response, employing the Bayesian binning method described in [6, 7].
3. Divide the mutual information by the **stimulus presentation duration T** to determine the **information transmission rate** $\mathbf{I}_R = \frac{\mathbf{I}}{\mathbf{T}}$.

Experiment

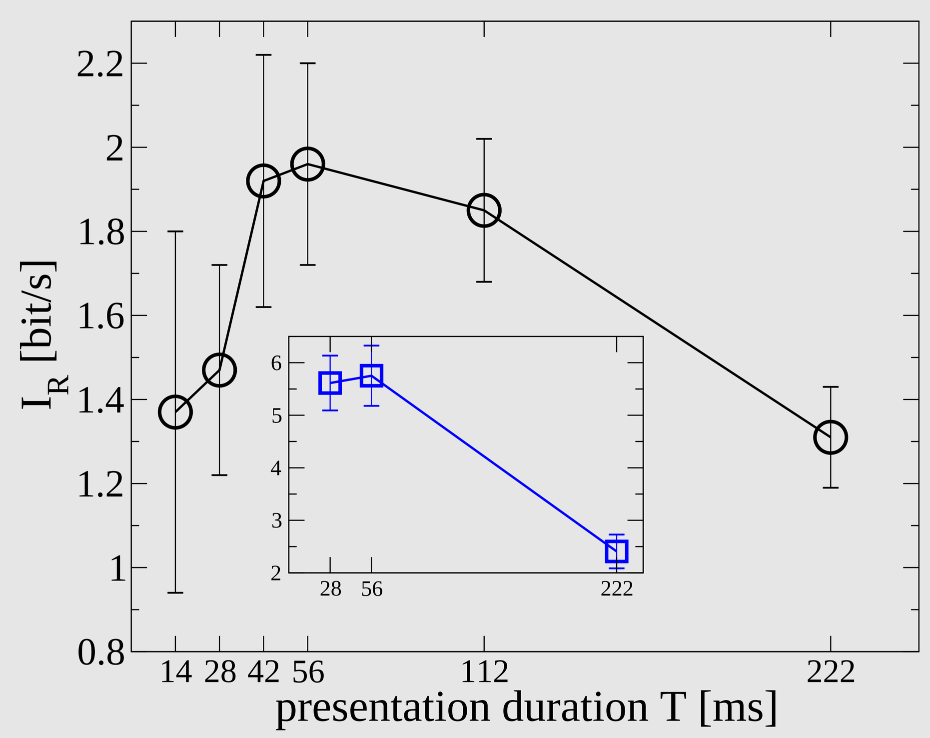
Mutual information I between stimulus label and response

- 28 cells tested at presentation durations between 14 ms - 222 ms, between 24-353 trials/stimulus [1, 3].
- 8 stimuli selected to span the response range of the cell (2 high, 2 low, 4 medium)



Result: mutual information increases with presentation duration.

Information transmission rate I_R



- Inset: 5 cells tested with 35 stimuli [4].

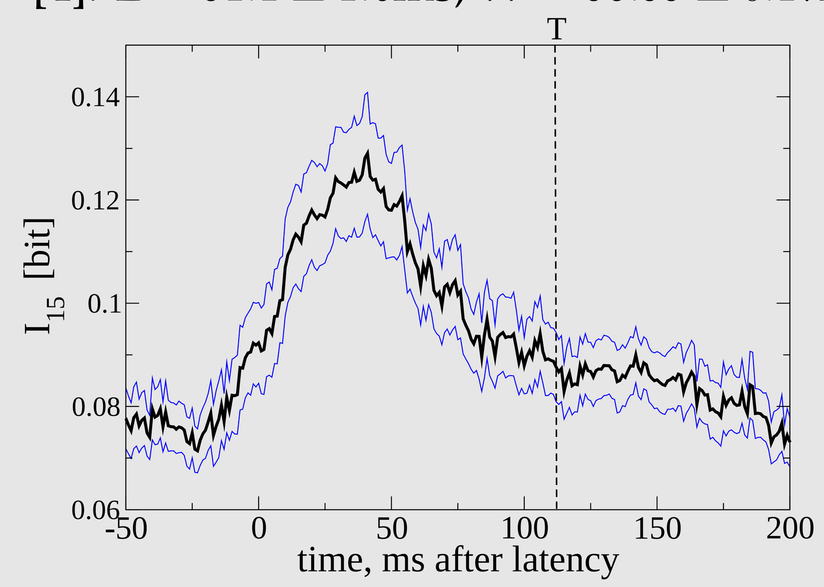
Result: information transmission rate peaks in the presentation duration interval [42 ms,110 ms] for 8 stimuli, and in the interval [28 ms, 221 ms] for 35 stimuli.

Question: what happens when the number of stimuli is increased?

Experiment

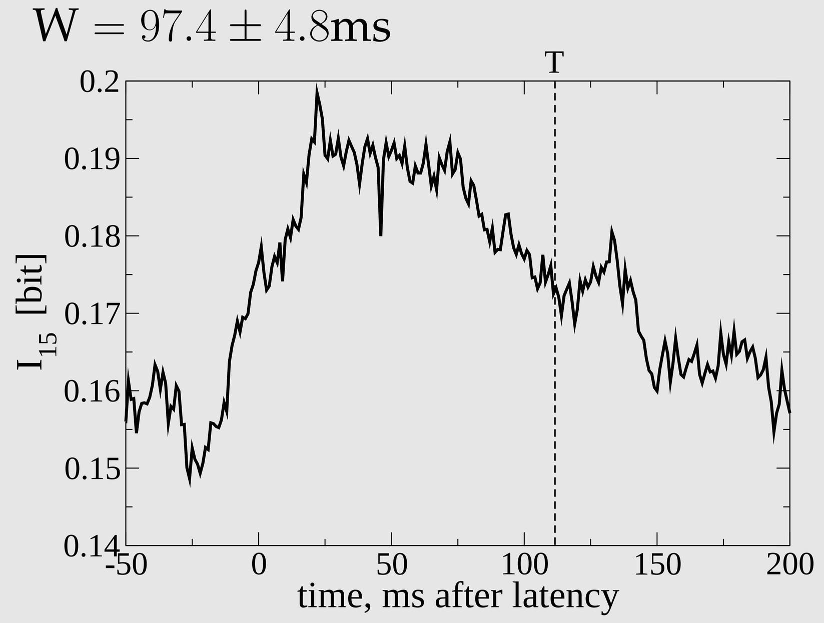
Mutual information in a 15 ms sliding window I_{15}

- 16 cells, 76 stimuli, T=110 ms, 10-30 trials/stimulus [4]. L $= 91.1 \pm 1.6$ms, W $= 95.99 \pm 0.17$ms



Result: information transmission rate begins to decrease 50-60 ms after response onset.

- 1 cell tested with 600 stimuli, T=110 ms, 15 trials/stimulus [2]. L $= 109.1 \pm 2.9$ms, W $= 97.4 \pm 4.8$ms



Result: even with a large stimulus set, information transmission rate begins to decrease prior to a stimulus duration **T** after the latency.

Conclusion: if you want to determine the selectivity of STSa cells efficiently, speed up the presentation rate to about 10-20 stimuli/s. That this works was also demonstrated in [8, 9, 2].

References

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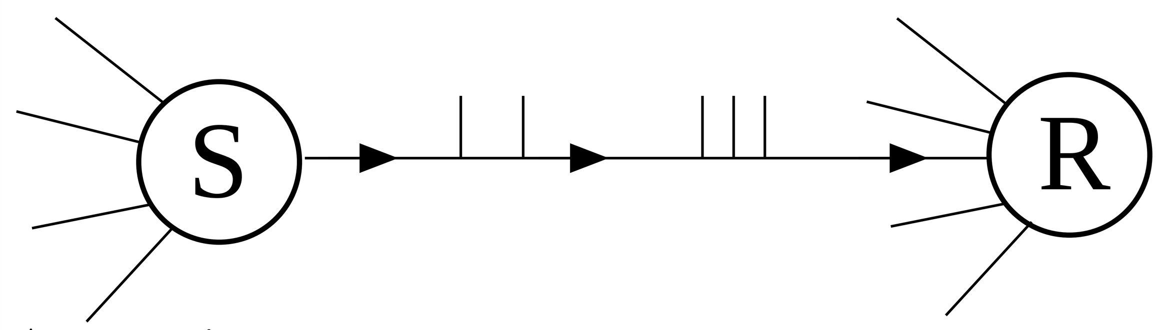
Theory

Do neurons maximise spike efficiency?

We consider a simple sender-receiver scenario, where one neuron (S) sends messages (e.g. stimulus features) to a receiving neuron (R) which tries to decode the message.

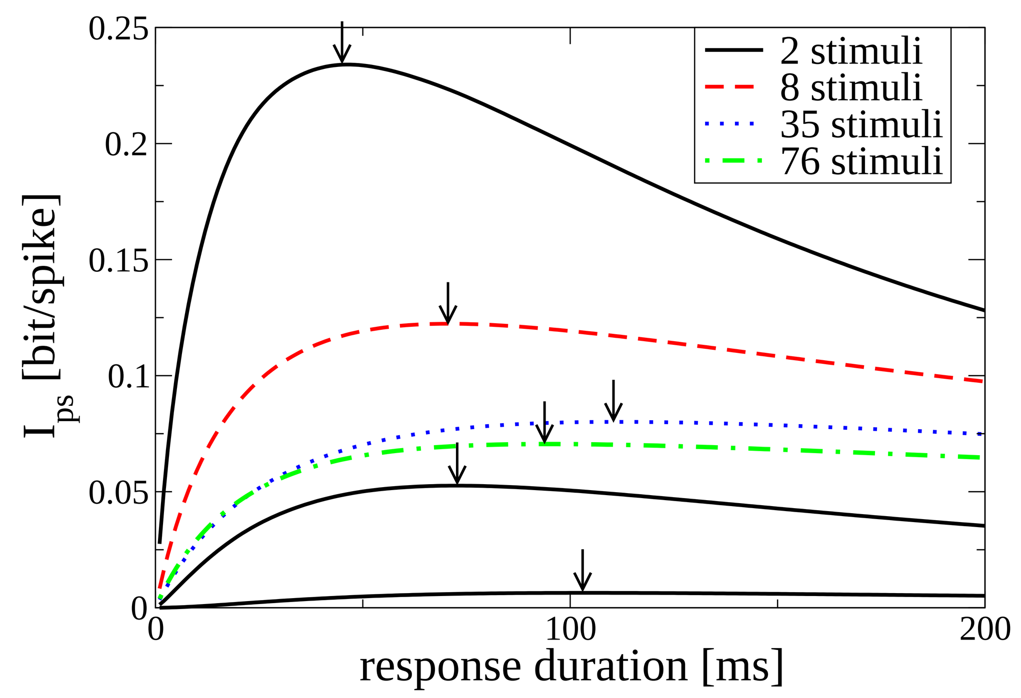


Assumptions:

- The receiver knows the sender's prior distribution over the possible messages.
- Messages are encoded in the firing rate, or firing probability.
- Spikes are generated independently of each other.

Let M_s be the sent message, and M_r be the received message. We can then compute the joint distribution $P(M_s, M_r)$ and hence the mutual information $I(M_s; M_r)$. Dividing this information by the expected number of spikes generated in the message passing process yields the information transmitted per spike, or **spike efficiency** $\mathbf{I}_{ps}$.

- Firing rates: from maximally 80 spikes/s to 10 spikes/s background activity.
- Stimulus priors: uniform for 8 and 35 stimuli (as in the experiments). 2 stimuli: 0.1 (top curve), 0.01 (middle curve), 0.001 (bottom curve).



Result: theoretical spike efficiency peaks in (roughly) the same time interval as the information transmission rate.

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