Do action potential waveforms convey extra information?

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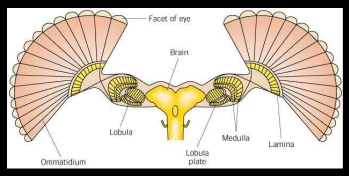
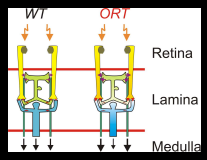
Acknowledgements: *Anette Harsch, Ingo Kleppe, Hugh Robinson & Mikko Juusola (Dept. Physiology, University of Cambridge)*

Funding: MCyT, fBBVA, CAM, Royal Society

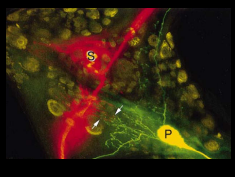
Ongoing projects

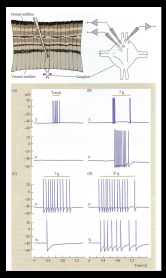
Molecular machinery behind MaxInfo using Drosophila mutants





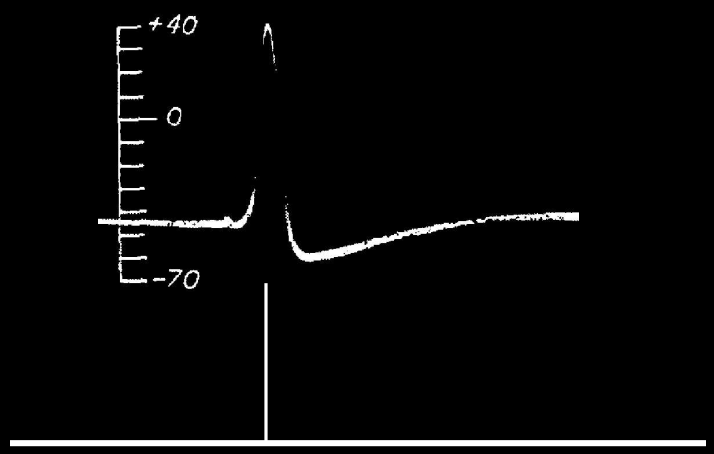
Neuronal computations in small networks (Multirecordings, imaging and behaviour simultaneously)



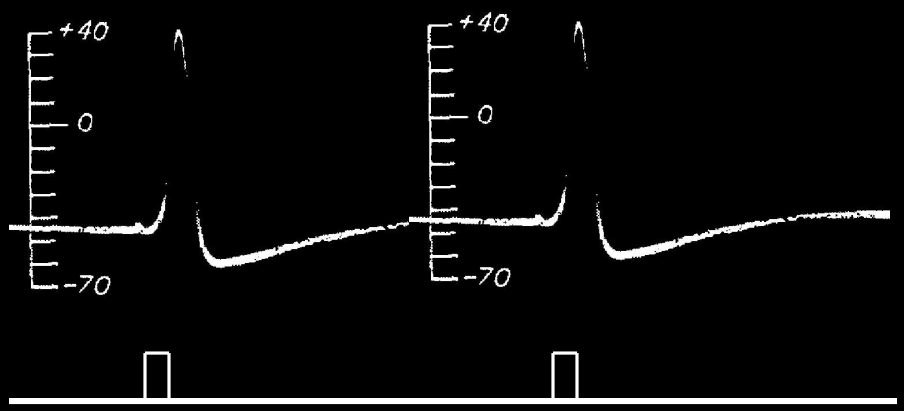


Motion detection
Types of codes
Multimodal coding
Memory
Decisions
Sensorimotor integration
Use of predictive information

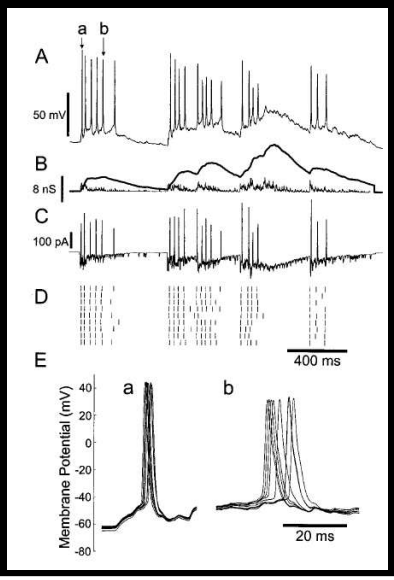
Encoding studies assume steretyped AP



Waiting for conductances to reach equilibrium produces stereotyped AP



Naturalistic input (bombardment of EPSPs) gives different AP shapes



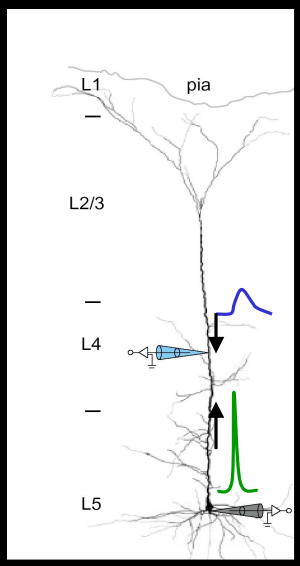
Harsch & Robinson (2000)

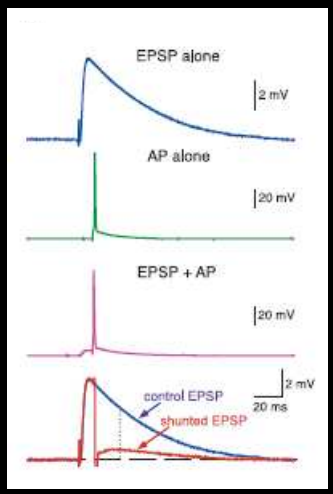
AP shape important in neuronal biophysics

1. K^+ channels: activity-dependent broadening
   (Geiger & Jonas, 2000)
2. Na^+ channels: activity-dependent lowering
   (Geiger & Jonas, 2000; Grussman et al., 1979; Wang and Kaczmarek, 1998).
3. AP shapes influence EPSPs

   (Sabatini and Regehr, 1997; Qian and Saggau, 1999; Stewart and Foehring, 2001; Stuart et al., 2001; Geiger and Jonas, 2000; Brody and Yue, 2000; Prakriya and Mennerick, 2000; He et al., 2002; Meeks and Mennerick, 2004).

4. AP shapes interact with incoming EPSPs

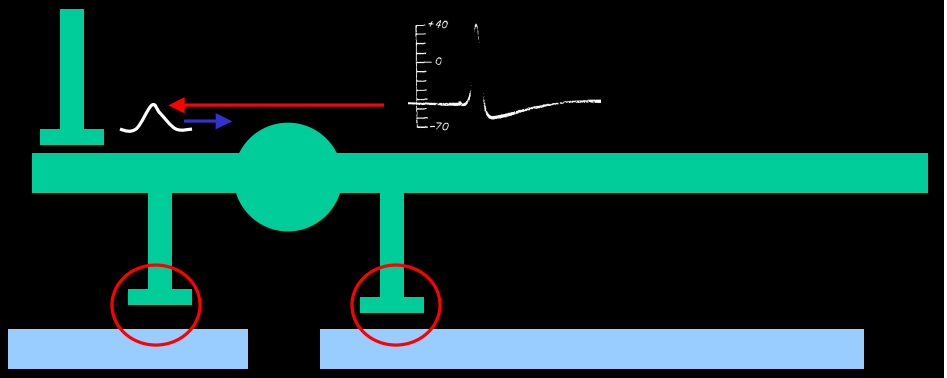




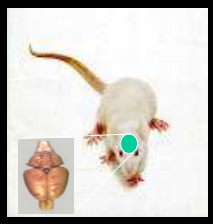
Hausser et al. (2001)

HYPOTHESIS:

AP shapes encode features of the stimulus to participate in neuronal codes (for local processing)



Experiments in cortical slices



'Naturalistic' stimulation by conductance injection (dynamic-clamp)

Current injection

$$C\frac{dV}{dt} = I_{PA} + I_{stimulation}(t)$$

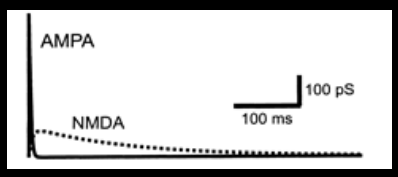
Conductance injection

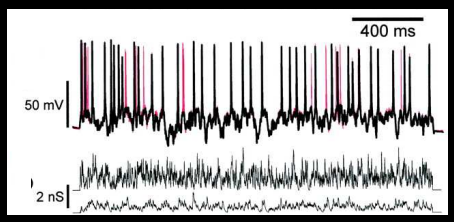
$$C\frac{dV}{dt} = I_{PA} + g_{stimulation}(t)\left(V(t) - E_{rev}\right)$$

$$I(t) = g(t)[V(t) - E_{\text{rev}}]$$

$$I(t) = g_{AMPA}(t)[V(t) - E_{AMPA}] + g_{GABA}(t)[V(t) - E_{GABA}] + \frac{g_{NMDA}(t)}{1 + k_1 \exp(-k_2 V(t))}[V(t) - E_{NMDA}]$$

$$g(t) = \sum_i g_i(t) \qquad g_i(t) = \bar{g}[\exp(-(t - t_i)/\tau_d - \exp(-(t - t_i)/\tau_r]$$

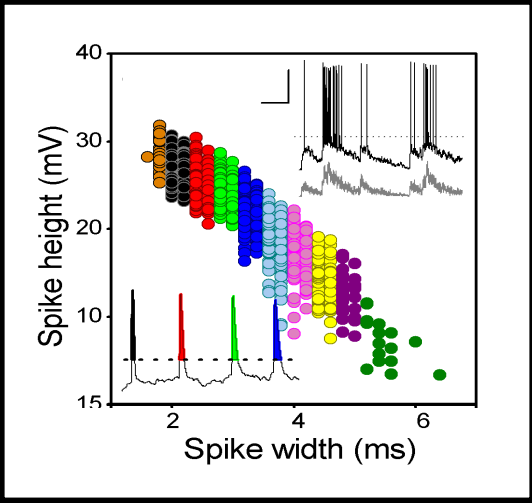




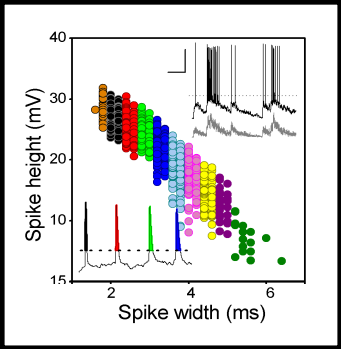
Summary of experimental protocol

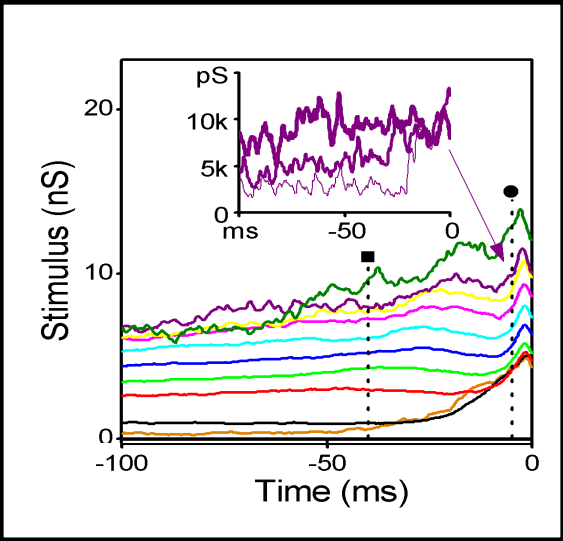
1. **Prep: Slices of rat occipital cortex (13-23-d-old Wistar rats)**
2. **Block of intrinsic synaptic conductances (CNQX, APV, bicuculine)**
3. **Electrophys: Whole-cell 4-6 MΩ, conductance injection of (modulated-) Poisson EPSPs**
4. **Temperature: 21-23° (n=32), 34° (n=24)**

Under 'naturalistic' stimulation there is AP shape variability



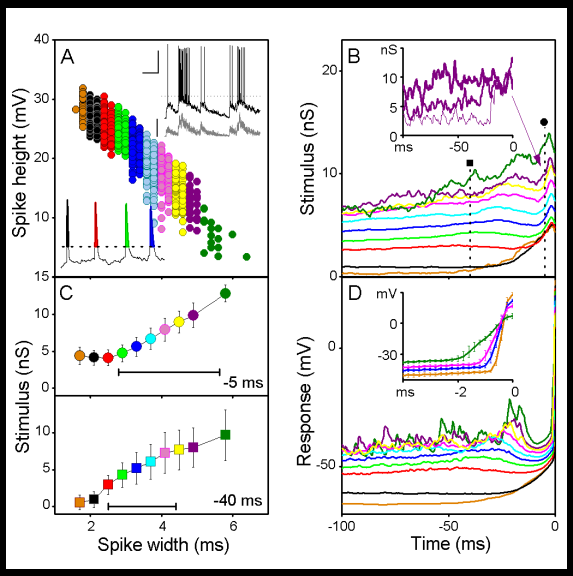
AP shape correlates with stimulus amplitude



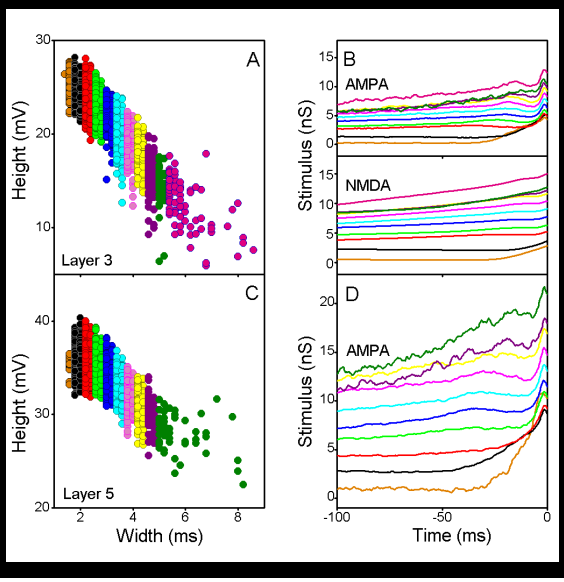


Do Action Potential Waveforms Convey Infomation about the Stimulus?

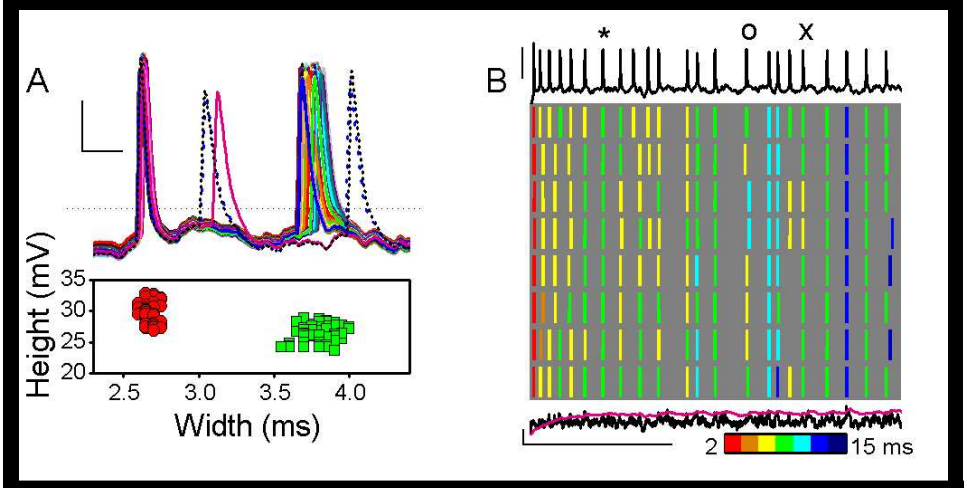
Time scale for encoding < 50 ms



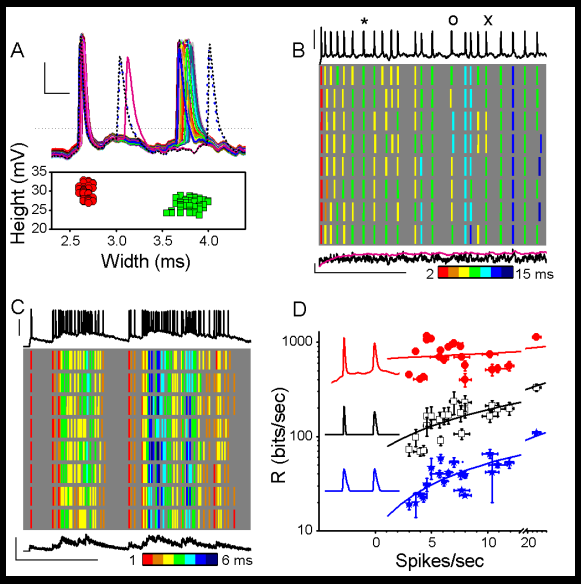
Independent of layer and synaptic conductance cocktail



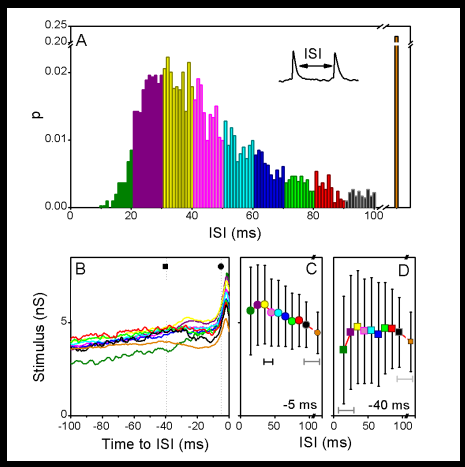
Reliable AP shapes in repetition experiments

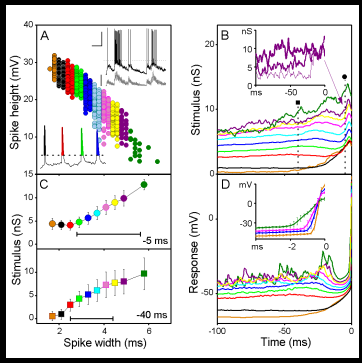


AP shapes have four times the Information Rate of spike times

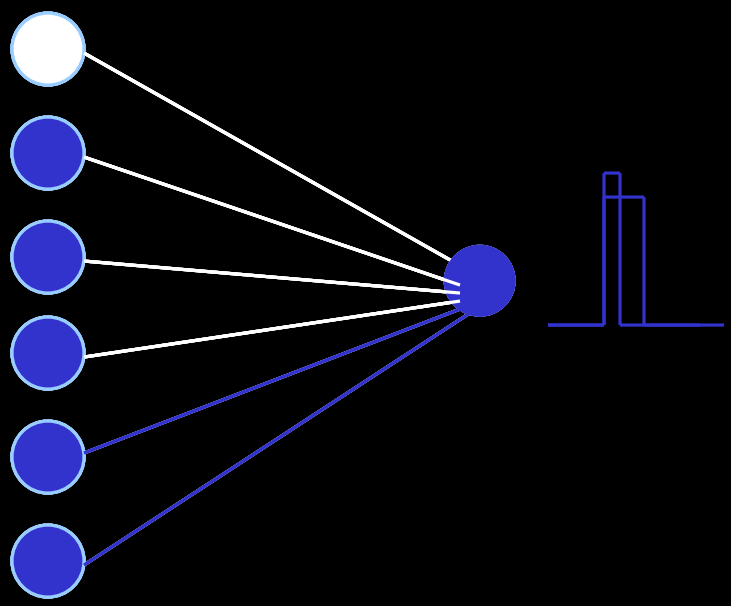


Spike times have low correlation to stimulus





What could the AP shape be used for?



Conclusions

Action potentials (in these experiments):

1. Are not stereotyped (not new)
2. They carry information about the synaptic conductance amplitude 50ms of previous stimulation
3. This information has low noise
4. This information is not in the ISIs
5. Biophysical evidence (from other labs) suggests it may participate in networks, but we do not know yet (future work)
6. More for future: *in vivo*