Introduction

- Many animals are sensitive to small timing differences in sensory stimuli.
- Anatomical and physiological studies of time coding experts such as weakly electric fish, barn owls, and echolocating bats have shown delay-lines and coincidence detectors to be common solutions for detecting small timing differences (Carr, 1993).
- Inhibition also plays a critical role in processing submillisecond spike timing differences in auditory duration tuning and sound localization.

Peripheral receptors encode stimulus duration into spike timing differences

- Knollenorgans (KOs) on opposite sides of the body perceive opposite polarity images of the same stimulus.
- The spike timing difference between KOs represents the duration of the signal (Hopkins and Bass, 1981).

Peripheral spike times from different receptive fields are compared in the midbrain

This anatomy leads to the hypothesis of delay-line anti-coincidence detection at Small Cells.

Materials and Methods

Retrograde labeling of Small Cell axons

- Recording from labeled axons

Confirmation that recordings are from Small Cells

- Antidromic stimulation elicits a response

Duration Tuning is Diverse

Responses to square pulse stimuli of varying duration and polarity

- Long-pass tuning

Multiple Excitatory Inputs to Small Cells

Responses to both stimulus edges

- nELL Projection: Small Cell soma ratio greater than 1

Inhibition Modifies Duration Tuning

Paired pulses suggest inhibition of Small Cells

- Down edges block responses of Small Cells but not of knollenorgans

Blocking inhibition changes duration tuning

- Confirmed duration tuning

Proposed Model

- Peripheral receptors act as long-pass filters at lower stimulus intensities (Lyons-Warren et al, 2012).
- \( \Delta t_E - \Delta t_I \) determines the shape of the duration tuning curve. The duration of the inhibitory window is determined by the relative timing of \( \Delta t_E \) and \( \Delta t_I \). In the absence of inhibition, coincidence detection of the two excitatory inputs may result in band-pass tuning.

Conclusions

- Our data suggest a new type of delay-line based temporal coding with a novel role for precisely timed inhibition.
- Delayed start-excitation paired with stop-inhibition is similar to mammalian auditory duration tuning, which may also rely on precisely timed inhibition and excitation in response to the start and stop of a sound.
- Excitation and inhibition from the same stimulus edge is similar to mammalian sound localization which uses inhibition to modify coincidence detection of two excitatory inputs.
- For electroreception, precisely timed inhibition paired with same side excitation creates narrow blocking windows for maximal temporal resolution.

References & Acknowledgements


How do Small Cells integrate inhibition with delayed excitation to process submillisecond spike timing differences?