Electrical Micro-Stimulation of Cat Retina Evokes Precisely Timed Cortical Spikes: A Possibility for Information Transmission Using a Retina Implant

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Goal. Specific electrical stimulation of retinal ganglion cells for the development of a retina implant for blind humans with damaged photoreceptors. Basic visual perception may be provided even with few electrodes if spatial and temporal stimulation patterns are optimized such that the evoked cortical activity reflects as much visual information as possible.

Methods. Retinal ganglion cells of anesthetized cats are electrically stimulated by epiretinally placed microelectrodes with biphasic impulses of 200 µs phase duration and varied current amplitude while single-unit spike trains and population activities (LFP: 1-140 Hz; MUA: 1-10 kHz) are recorded via multiple microelectrodes from area 17 and 18. Subsequently, information transmission from stimulus to first cortical spike is calculated using information theory. The higher the temporal precision of cortical spikes (i.e. the lower their standard deviation), the more Shannon information can be transmitted with each spike about the stimulus, provided the mean responses are distinguishable.

Results. Mean delays between retinal stimulus and the first evoked spikes range from 6 to 8 ms. The standard deviation of single recordings ranges from 0.2 to 3 ms indicating a high temporal precision. Both values significantly depend on the stimulus current: they decrease with increasing current amplitude. The Figure shows responses evoked by identical stimulus currents via two retinal stimulation electrodes (300 µm apart) with a relative delay of about 200 µs. Application of information theory yielded the mutual information between retinal stimulus and the time of the first spike. Values are 0.2 to 0.6 bit per spike depending on the amplitude of the stimulation current.

Conclusions. Epiretinal electrical stimulation of retinal ganglion cells can evoke precisely timed cortical spike responses. However, in future work temporal and spatial stimulation patterns have to be optimized in parallel to provide maximal information transmission with retina implants.

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First Spike Responses in Area 17 by Electrodes A and B

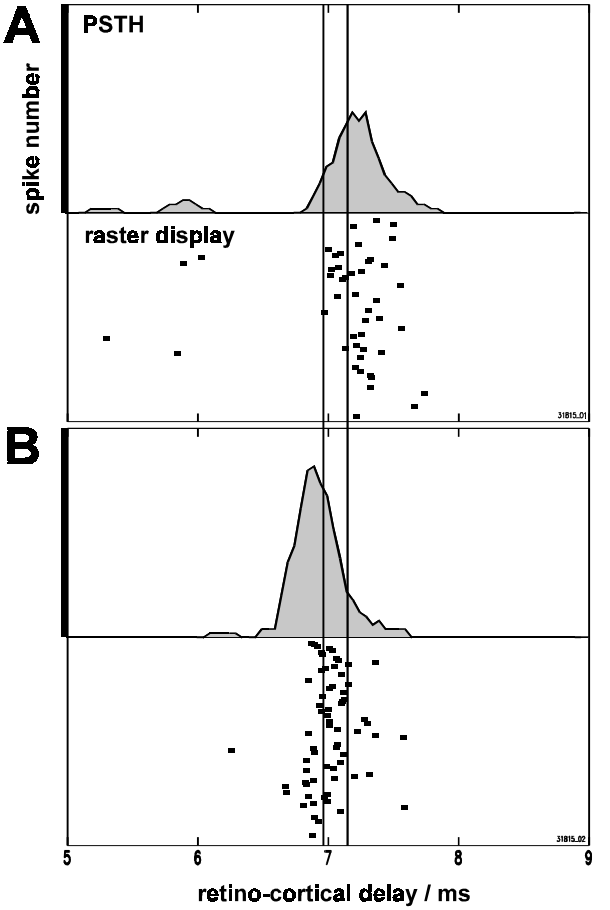

Figure: A, B show cortical spike responses evoked by electrode A and B, respectively. In A and B, the upper panels display smoothed PSTHs, the lower panels raster diagrams of single spike responses. The scale bar is 10 spikes per bin (50 µs bin width). The vertical lines indicate the mean (7.15 and 6.96 ms). Mutual information is 0.5 bit / spike.