Introduction

Within the development of a retina implant for blind humans with degenerated photoreceptors, optimization of electrical stimulation of retinal ganglion cells is necessary.

A strategy that simply aims for maximum cortical activation is not sufficient, unless evoked cortical activity reflects visual information coded in the electrical stimuli. Only then, the goal of restored basic visual perception might be attained.

However, electrical retinal stimulation is constrained to the number of electrodes, tissue-safe currents and low power consumption. Here, we apply information theory ❶ to face the task of maximizing the retino-cortical information transfer under the given constraints. Moreover, a high information transfer requires a low signal-to-noise ratio of the evoked responses and distinct temporal and spatial cortical activation.

Methods

- Retinal ganglion cells of anesthetized cats are stimulated by epiretinally placed microelectrodes while single-unit and population activity (local field potentials LFP: 1 - 150 Hz, multi-unit activity MUA: 1 - 10 kHz) is recorded via multiple microelectrodes from the primary visual cortex ❷.
- Irregular pulse trains ("events") act as triggers for electrical stimulation current waveforms or visual stimulus patterns. These "symbols" are randomly drawn from a stimulus symbol set. Stimuli of one set may vary in stimulation parameters e.g. such as current amplitude, phase duration or inter-phase delay ❸.
- Principal component analysis is applied to reduce the dimension of the cortical responses. Thus, response time courses may be described by a set of principal component coefficients ❹.
- After estimation of the conditional probabilities using an artificial neural net (see acknowledgement) or a classification method, mutual information is calculated ❺ ,❻.

Preliminary Results

- The mean mutual information ranges between 0.05 and 0.5 bit per stimulus symbol ❻.
- The retino-cortical information transmission depends strongly on the symbol set, and thus, on the stimulus parameters varied .
- Evoked cortical responses have to be distinct and correlated to the stimulus symbol.
- A high signal-to-noise ratio is necessary to achieve high information transmission.

Conclusion

Information theory allows the quantification of retino-cortical information transmission and might help to design electrical stimuli suitable to restore basic vision with retina implants.

Literature

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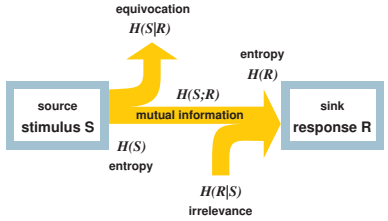
Acknowledgement

We thank B. J. Richmond from the Laboratory of Neuropsychology, National Institute of Mental Health, Bethesda, U.S.A. for providing us with the backpropagation neural net.

Supported by BMBF, grant 01 IN 501 F to R. Eckhorn

1 The Discrete Information Channel



mutual information:

$$H(S;R) = H(R) - H(R/S) = \sum_S p(s) \sum_R p(r/s) \cdot log_2 \frac{p(r/s)}{p(r)} \quad (1)$$

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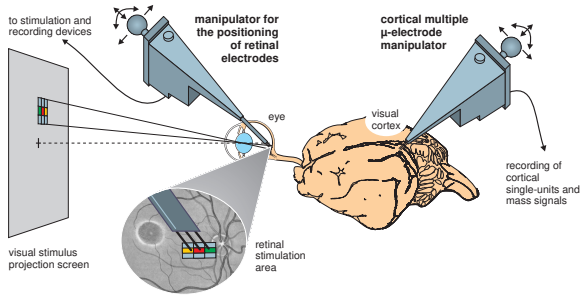
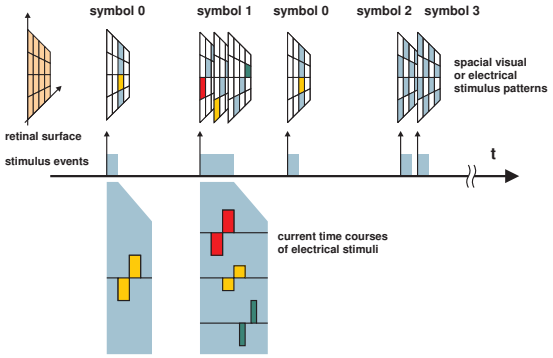
$$= \frac{1}{n} \sum_{i=1}^{R} \sum_S p(s/r_i) \cdot log_2 \frac{p(s/r_i)}{p(s)} \quad (2)$$

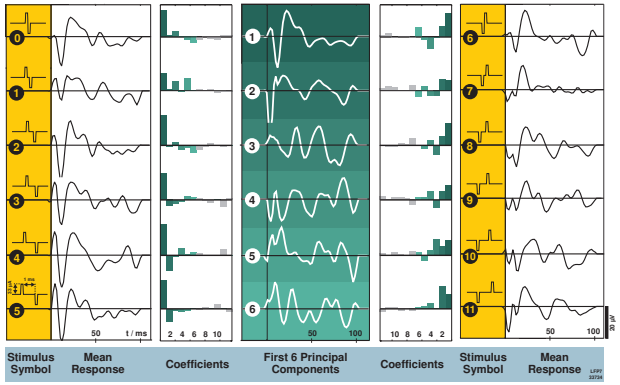
2 Experimental Setup



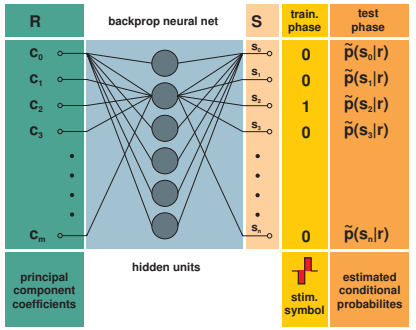
3 Event Triggered Random Sequence of Visual and Electrical Stimulus Symbols

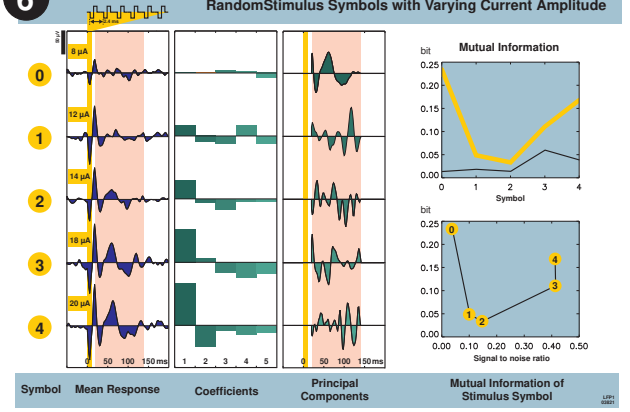


4 Principal Component Analysis of Cortical Local Field Responses Evoked by Random Temporal Stimulus Symbols with Varying Interphase Delay



5 Calculation of the Mutual Information by Estimating the Conditional Probabilities



- **Training phase:** For each trial of the training data the response measures (principal component coefficients) are taken as input to the neural net. Accordingly, the stimulus symbols are applied to the output.
- The backpropagation algorithm is used to adjust the weights.
- **Test phase:** The principal component coefficients of the test data are used to feed-forward calculate estimates of the conditional probabilites p(s|r).
- With equation (2) the mutual information may be calculated.

6 Principal Component Analysis of Cortical Local Field Responses Evoked by RandomStimulus Symbols with Varying Current Amplitude