Improving Spatial Resolution and Selectivity of Transcorneal Electrical Stimulation by Temporal Interference Technology

Saidong Ma, Xiaoyu Song, Tianruo Guo, Feng Zhou, Zhengyang Liu, Xinyu Chai, Liming Li*

School of Biomedical Engineering, Shanghai Jiao Tong University, Shanghai, China

Graduate School of Biomedical Engineering and Tyree Institute of Health Engineering, UNSW, Sydney, Austrilia

Introduction

Temporal interference stimulation (TIS) has been reported to induce electric fields focalizing on local neuronal targets. Despite the competent feasibility of retinal TIS, the interpretation of characteristics of spatial resolution and selectivity under TIS remains rudimentary.

In this study, we conduct ***in silico* investigations** to understand the characteristics of spatial selectivity and resolution using **a finite element model of a multilayered eyeball and electrode configurations**. By simulating different metrics of electric potentials envelope modulated by TIS, our model supports the possibility of **achieving mini-invasive and spatially selective electrical stimulation using retinal TIS**.

Conclusions

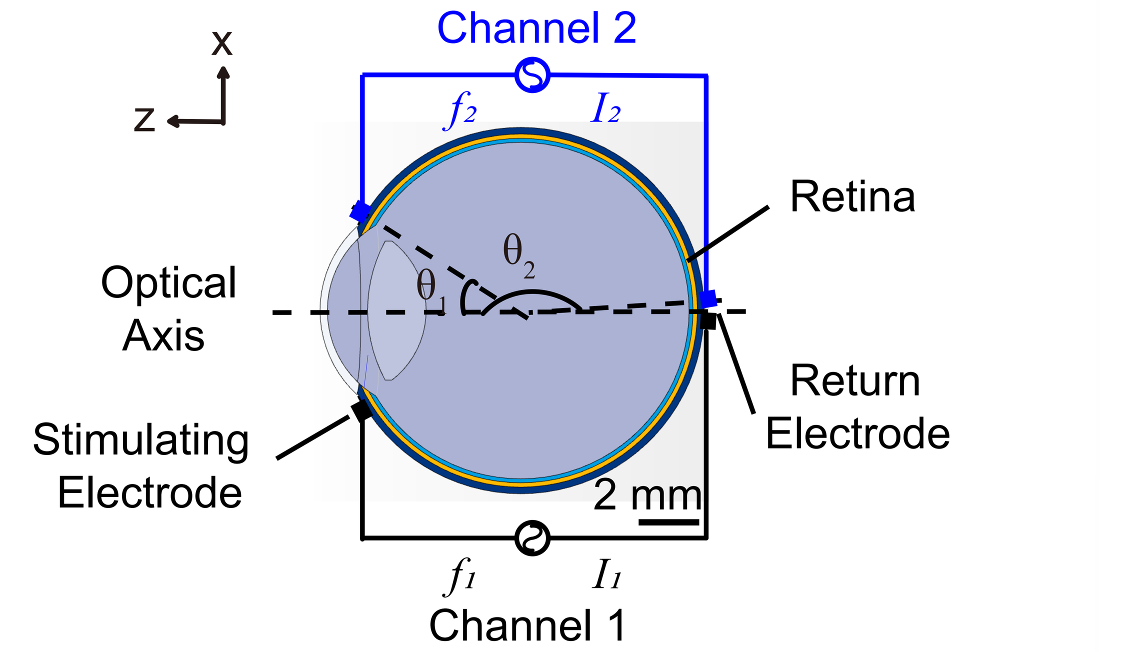
- **Spatial distributions of electriic potential (EP) envelope** varied as specific distribution patterns **(unimodal, or non-unimodal pattern)**
- Performances of **spatial resolution and selectivity** can be evaluated through the **influences of electrode parameters on metrics of EP peak**
- **Current steering** can be beneficial for characterizing **TIS-induced focality and spatial selectivity**

Clinical Relevance

- This study provides a **theoretical basis** for understanding how the design of electrode configuration impacts transcorneal TIS performance.
- This model can guide future **development of transcorneal TIS configurations and stimulation strategies** that may benefit patients with inherited retinal diseases.

Methods

Finite Model of Eyeball and Electrodes



Eyeball Structure

Sclera, choroid, retina, vitreous body, lens, atria, and cornea

Electrode Configuration

Stimulation channels

- Channel = Stimulating Electrode + Return Electrode
  Channels are axial symmetrical about the optical axis

Disc Electrode properties

- Material = Platinium
  Diameter = 1 mm Thickness = 50 μm

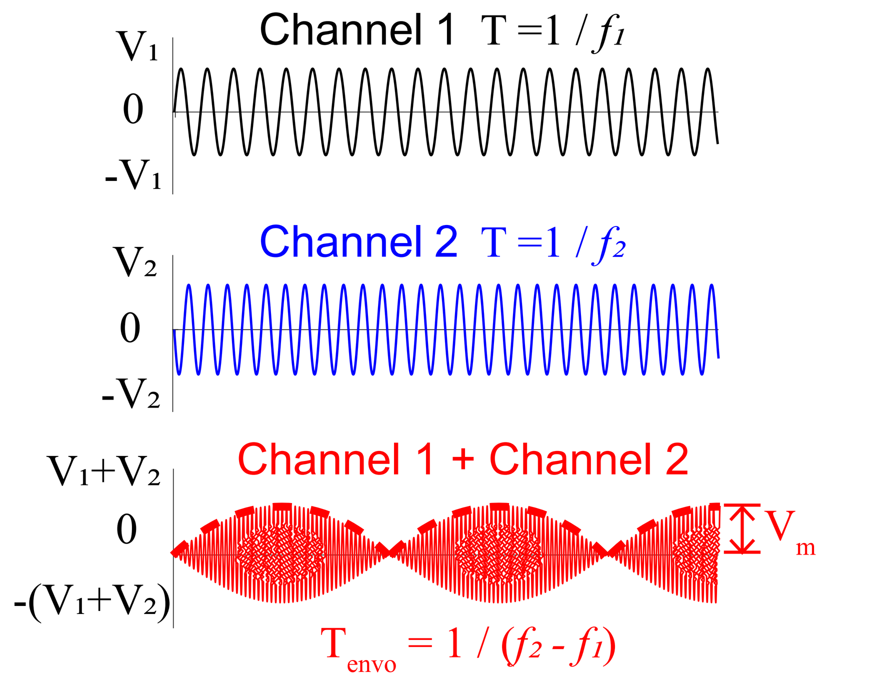
Electrode placement

- θ_1 = angles between stimulating electrodes and the optical axis
  θ_2 = angles between return electrodes and the optical axis

Current Steering

$$\alpha = \frac{I_1}{I_1+I_2}$$

TIS-induced EP Waveforms



the Maximum Value of the EP Envelope (EP peak, V_m)

$$V_m = V_1 + V_2$$

Analysis of EP peak

1) Distribution Patterns
Patterns of spatial distribution of envelope over the retina

2) Peak Value
Maximum value of EP waveform

3) Peak offset
Maximum angle between positions of peaks with different current ratio

4) Peak Width
Distance between sides of a peak measured at 90% of the peak height

We can apply **temporal interference technology** on **transcorneal electrical stimulation** to improve the spatial focality and selectivity, by evaluating the performances of EP peak metrics with optimal ranges of electrode parameters and current steerings.

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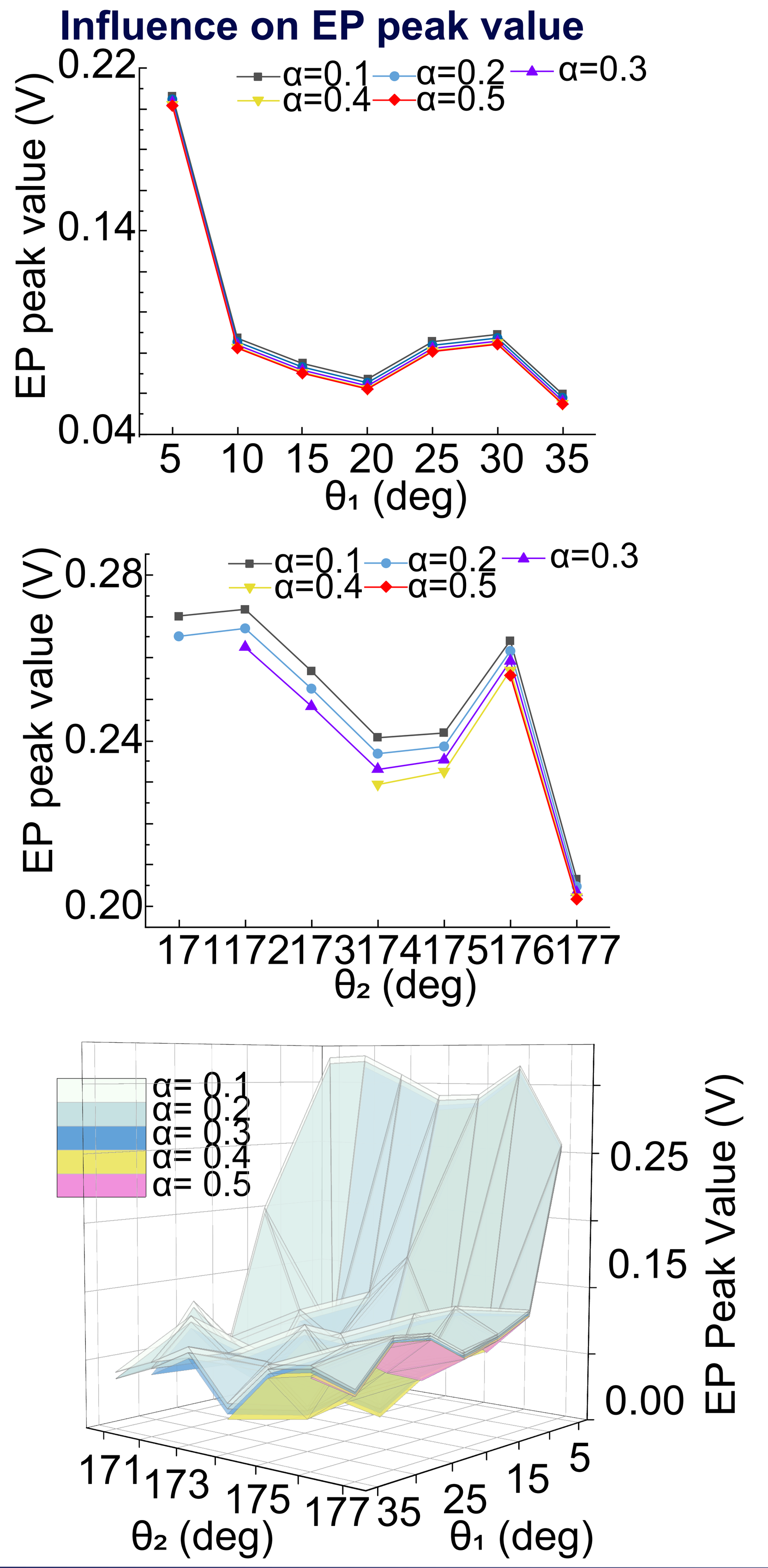
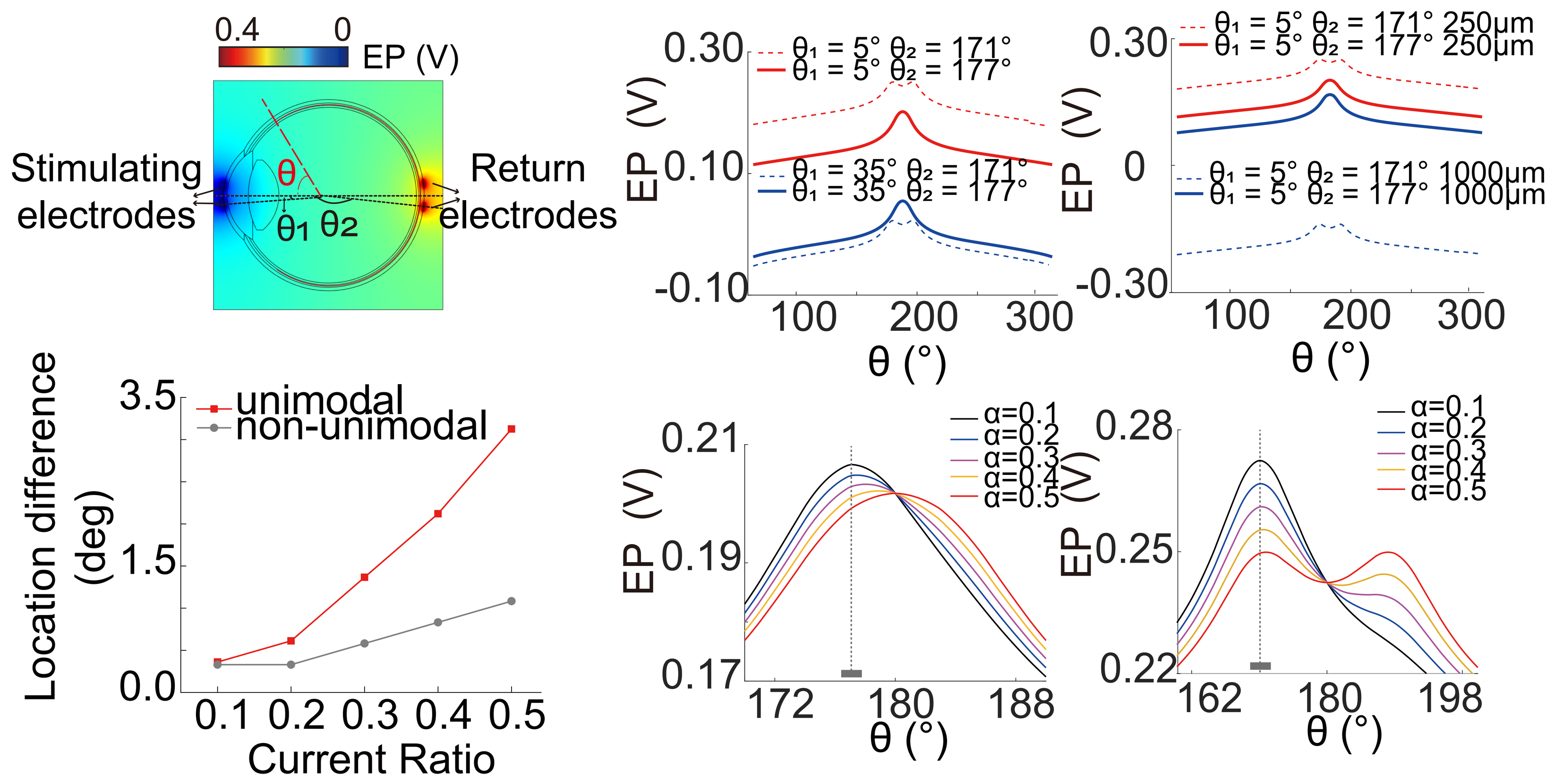
Results

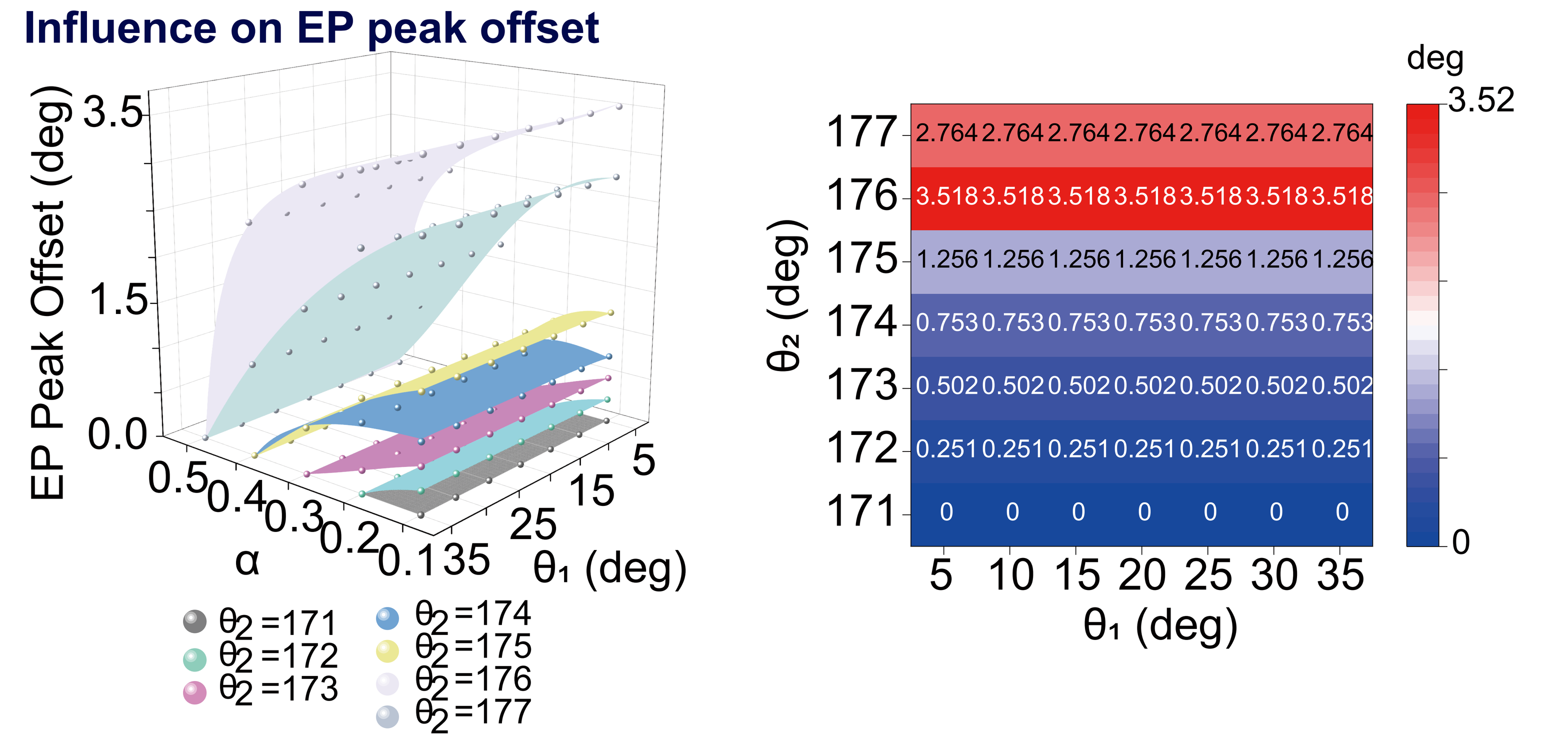
Influence on EP peak value



Influence of electrode parameters on distributions of EP peak



Influence on EP peak offset



Results

The unimodal patterns reflect a better performance of spatial resolution and selectivity;

Both stimulating and return electrode positions have **non-linear influences** on the distributions of **peak values**, the **optimal electrode positions** are θ2 ranging from 176° to 177° and θ1 ranging from 5° to 10°;

θ1 cannot affect the value of peak offset, while current ratio and θ2 have a non-linear effects on the **peak offsets**, optimal electrode positions of θ2 ranging from 176° to 177° were validated through these findings;

Electrodes sizes ranging from 750 to 1250 μm should be more practical to use.

Influence on EP peak width