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Cortical Dynamics of Phosphene Perception: A Study Using EEG Signals

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INTRODUCTION & AIM

Scientific evidence has shown that electrical stimulation of the primary occipital cortex can evoke luminous visual perceptions known as phosphenes. This finding has provided the basis for the development of cortical visual prostheses for blind individuals. In this context, understanding and unveiling the cortical perceptual dynamics evoked during the process of perceiving phosphenes is crucial to improving the interaction between this technology and the user.

Aum. We investigated the cortical perceptual dynamics of three blind subjects who were implanted with a 10x10 Utah microelectrode array in their visual cortices. Cortical responses during the perception and non-perception of evoked phosphenes were monitored using electroencephalographic (EEG) techniques. Processing methods included quantification of event-related synchronization/desynchronization (ERS/ERD) and directed transfer function (DTF)-based connectivity analysis.

METHODS

Procedure for the implantation of the microarray

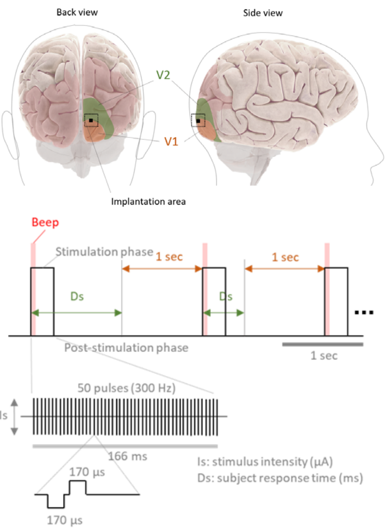


Fig. 1 Pre-implant procedures for transcranial magnetic stimulation. Utah array 10x10 electrode implanted in the primary visual cortex. Stimulation protocol.

EEG recordings and processing

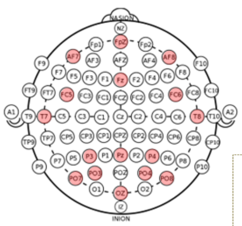
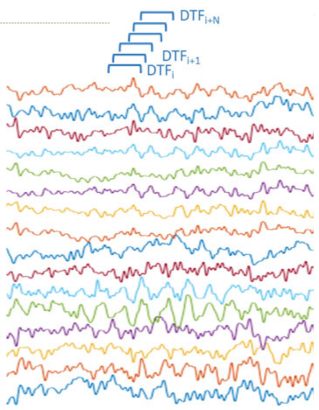
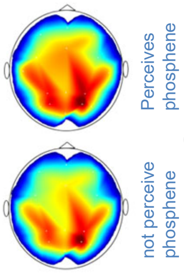


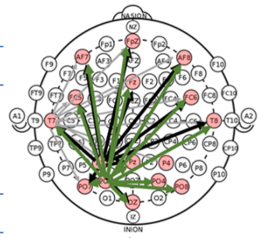
Fig. 2 Experimental setup for EEG signal recording. In the 10/20 system figure, the electrode positions whose recordings were considered in this analysis are highlighted.



Calculation of C-clustering

Calculation of the Directed Transfer Function (DTF)





RESULTS

ERD EEG

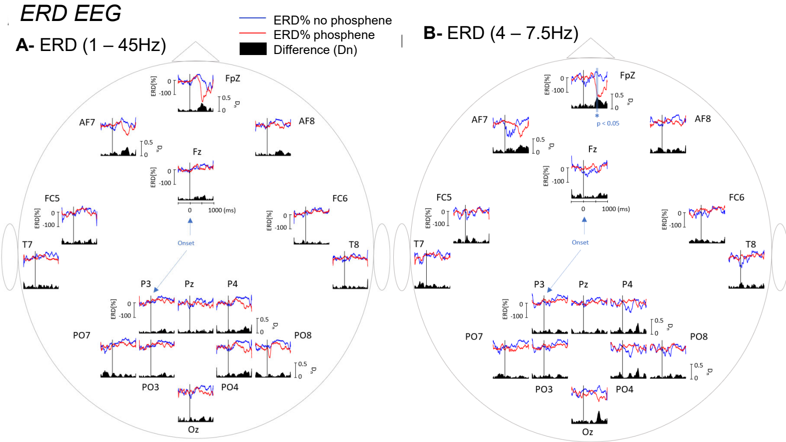


Fig. 3 A) Percentage desynchronization values obtained in the 1 to 45 Hz band. The area graphs over time display the differences (Dn values) between phosphene perception and non-perception. B) Percentage desynchronization values obtained in the 4 to 7.5 Hz band, showing a significant difference observed at FpZ.

Connectivity based on DTF

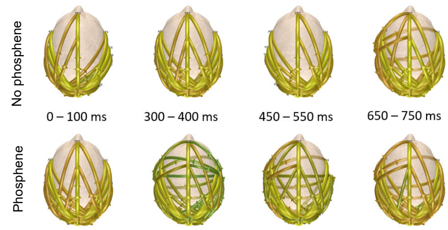


Fig. 4 Directional connectivity analysis in the 4 to 7.5 Hz band via DTF. The DTF in the corresponding intervals were averaged and represented during the shown post-stimulus intervals.

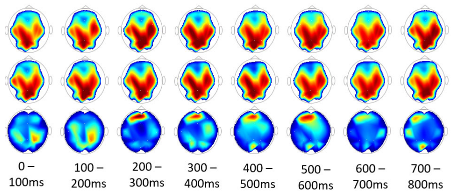


Fig. 5 Spatial distribution of c-clustering values. The top row corresponds to the non-perception of phosphenes. The middle row corresponds to the perception of phosphenes. The bottom row shows the difference between the perception and non-perception of phosphenes.

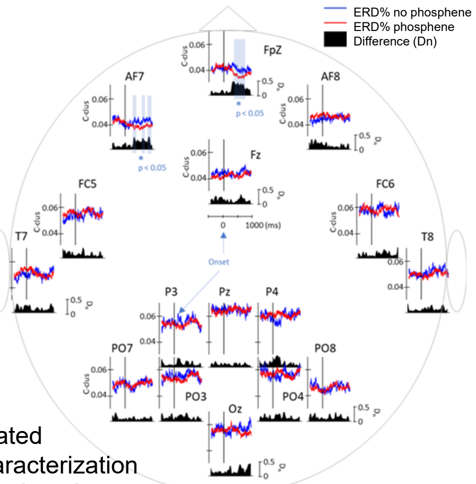


Fig. 6 Cortical connectivity analysis in the 4 to 7.5 Hz band. c-clustering values are presented for phosphene perception (red line) and non-perception of phosphenes (blue line). The black areas represent the Dn values (normalized mean differences). The lightly shaded areas indicate the time intervals where the differences are statistically significant.

CONCLUSION

In this study, we demonstrated that EEG signals allow characterization of cortical dynamics during phosphene perception.

It was observed that, in terms of evoked oscillation energy, frontal areas exhibit higher synchronization during phosphene perception, while in terms of directional connectivity, cortical directional information shows cross-modulation when the phosphene is perceived.