Influence of TMS-Coil Position on the Lateralization of Phosphenes Elicited by Magnetic Stimulation of the Visual Cortex

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***Abstract*—This study examines the dependence of phosphene position in the visual field on the site of transcranial magnetic stimulation (TMS). We found a strong negative correlation between the x-coordinate of the phosphene position in the visual area and horizontal position of the stimulation coil. It demonstrates the presence of a stable relationship between phosphene lateralization and TMS coil displacement in the horizontal plane. Obtained results can be valuable for the development of brain-computer interfaces (BCIs) with direct feedback including virtual reality applications.**

Keywords—phosphenes, transcranial magnetic stimulation (TMS), cortical mapping, visual cortex

I. Introduction

Phosphenes are artificial perceptions of light resulting from stimulation of the visual cortex [1,2]. They have been extensively studied using transcranial magnetic stimulation (TMS) because of the high spatial resolution of this technique, which allows precise mapping of the cortex [3]. In addition to theoretical interest, including the study of visual cortex interaction and the psychophysiological basis of visual perception, phosphenes hold potential for applications in brain-computer interfaces (BCI), virtual reality, and rehabilitation.

However, there is no reliable apparatus for inducing phosphenes with specific properties via TMS. Phosphenes show high variability in size, brightness and localization in the visual field [1,4]. In the present work we present the results of a study aimed at mapping the visual cortex of 8 healthy participants using single pulse TMS and exploring the relationships between positions of the TMS coil and coordinates of elicited phosphenes in the visual area. Cortical mapping was performed using individual models of the cortex obtained from MRI scans of the participants.

II. Materials and Methods

Eight healthy volunteers (1 female, mean age 21.37±1.81 years old) without any neurological or visual impairment participated in this study. Experimental session was performed in the dark room. During the session, up to 400 single pulse TMS stimuli were applied over the occipital cortex area within at an intensity of 120% of the threshold. The threshold was determined as To determine the position of the elicited phosphenes in the visual field, participants used a graphic tablet and a coordinate grid (168*168 cm) projected on the wall in front of them at a distance of 1 m. For the navigational TMS subjects underwent a magnetic resonance imaging (MRI) scan (1.5 T; Siemens, Germany) with a T1-weighted gradient-echo sequence. The gray matter surface of the brain was segmented using visor2™ (ANT Neuro, Netherlands) software for guiding the TMS coil placement. Since we used navigated TMS, we were able to analyze the coordinates of the TMS coil for each stimulus and correlate them with the coordinates of the perceived phosphenes. Pearson correlation was used to identify associations between phosphene coordinates and coil positions. For the visualization we used method of positioning TMS pulses on MRI-based brain model (described in details in [5]).

III. Results and Discussion

We collected a total of 607 phosphenes from 8 subjects (Table 1), including unilateral (e.g. contra- and ipsilateral, n=502), and bilateral phosphenes (n=63). Also, we identified 37 phosphenes, about the lateralization of which it is difficult to judge (multiple phosphenes). An example of the contralateral, ipsilateral and bilateral phosphenes is presented on Figure 1. Figure 2 depicts the dependence of the x-coordinate of phosphene position on horizontal TMS coil position (0x, Table 1) (however, 0y and 0z coordinates did not show any effects on phosphene position). We observed a significant negative correlation (median Pearson correlation

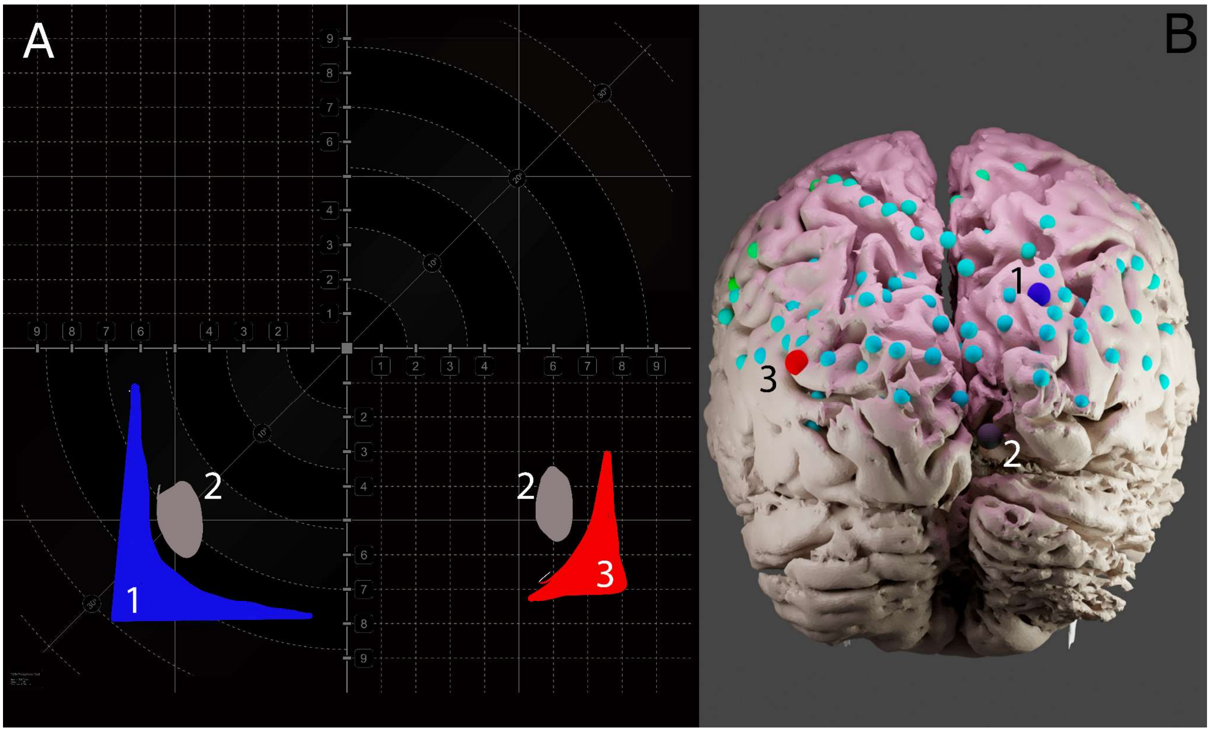

Fig. 1. **A.** An example of three phosphenes drawn by a participant AL (1,3- contralateral, 2- bilateral). **B.** Corresponding stimulated points projected onto a 3D cortical model reconstructed from the subject's MRI data.

coefficient r=-0.69, p<<0.01) reflecting the contralateral position of phosphenes. This indicates a stable contralateral dependence of the TMS-stimulated area of the occipital cortex and the position of phosphenes on the visual area. Figure 1 and Table 1 provide an assessment of the intra-individual character of the influence of the horizontal displacement of the TMS coil on the lateralization of the phosphenes, i.e. their position within the horizontal axis of the visual field. The most significant correlation was observed for participant AB, amounting to 81%, while the minimum values of the correlation coefficient, around 50%, were found in two participants - AK and FG. In the case of participant AK, a weak dispersion of phosphene positions was observed, while other participants showed a higher dispersion of phosphene occurrences.

IV. Conclusion

Our study provides results of precise TMS mapping of the visual cortex of 8 participants. Analysis of the phosphene maps revealed the character of the spatial distribution of these

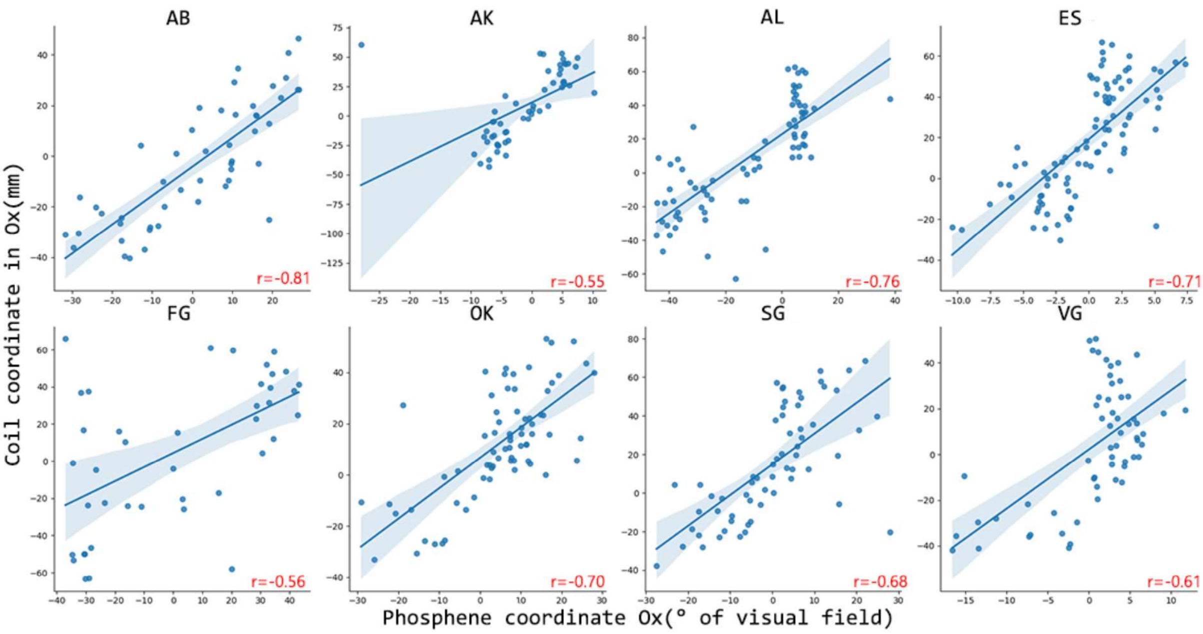

Fig. 2. Relationship between phosphene lateralization and TMS coil position along the horizontal axis for each of the participants.

TABLE I. THE TABLE PRESENTS DATA ON THE PEARSON CORRELATION COEFFICIENTS AND BETWEEN THE COIL DISPLACEMENT AXIS AND THE SINGLE PHOSPHENE LATERALIZATION

	Ox		Oy		Oz	
	Pearson	p-value	Pearson	p-value	Pearson	p-value
AB (n=49)	-0.810441	1.718896e-12	-0.271837	0.1453096	-0.496735	0.002929
AK (n=54)	-0.549356	1.692789e-05	-0.051420	0.2844694	0.218601	0.144794
AL (n=75)	-0.762599	1.871264e-15	-0.057041	0.7907509	-0.084495	0.135765
ES (n=91)	-0.713286	2.138834e-15	0.015034	0.6987700	-0.153034	0.154588
FG (n=41)	-0.558473	1.479041e-04	-0.092857	0.9132134	0.032753	0.679260
OK (n=71)	-0.699333	1.171226e-11	0.436854	0.0035261	0.138699	0.957062
SG (n=62)	-0.676608	1.576095e-09	0.130719	0.1312119	-0.137770	0.252378
VG (n=59)	-0.611179	2.727666e-07	-0.573700	0.0000003	-0.011514	0.727276

artificial light perceptions within the visual field. Despite high intra-individual variability and complexity in reliably identifying phosphene locations, we identified phosphene properties that can be robustly controlled by magnetic stimulation of the occipital area. These findings may inform future applications of phosphenes in BCI technologies, virtual reality, and rehabilitation [4,6,7].

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REFERENCES

[1] Kammer, T. (1998). Phosphenes and transient scotomas induced by magnetic stimulation of the occipital lobe: their topographic relationship. Neuropsychologia, 37(2), 191-198.

[2] Merabet, L. B., Theoret, H., & Pascual-Leone, A. (2003). Transcranial magnetic stimulation as an investigative tool in the study of visual function. Optometry and vision science, 80(5), 356-368.

[3] Fernandez, E., Alfaro, A., Tormos, J. M., Climent, R., Martınez, M., Vilanova, H., ... & Pascual-Leone, A. (2002). Mapping of the human visual cortex using image-guided transcranial magnetic stimulation. Brain research protocols, 10(2), 115-124.

[4] Gebrehiwot, A. N., Kato, T., & Nakazawa, K. (2021). Inducing lateralized phosphenes over the occipital lobe using transcranial magnetic stimulation to navigate a virtual environment. Plos one, 16(4), e0249996.

[5] Schaeffner, L. F., & Welchman, A. E. (2017). Mapping the visual brain areas susceptible to phosphene induction through brain stimulation. Experimental brain research, 235(1), 205-217.

[6] Syrov, N., Mustafina, A., Berkmush-Antipova, A., Yakovlev, L., Demchinsky, A., Petrova, D., & Kaplan, A. (2023). Single-Subject TMS Pulse Visualization on MRI-Based Brain Model: A precise method for mapping TMS pulses on cortical surface. MethodsX, 10, 102213.

[7] Hughes, C., Herrera, A., Gaunt, R., & Collinger, J. (2020). Bidirectional brain-computer interfaces. Handbook of clinical neurology, 168, 163-181

[8] Nam, C. S., Traylor, Z., Chen, M., Jiang, X., Feng, W., & Chhatbar, P. Y. (2021). Direct communication between brains: A systematic PRISMA review of brain-to-brain interface. Frontiers in neurorobotics, 15, 656943.