

Posterior alpha activity modulated by covert attention used as a control signal for BCI

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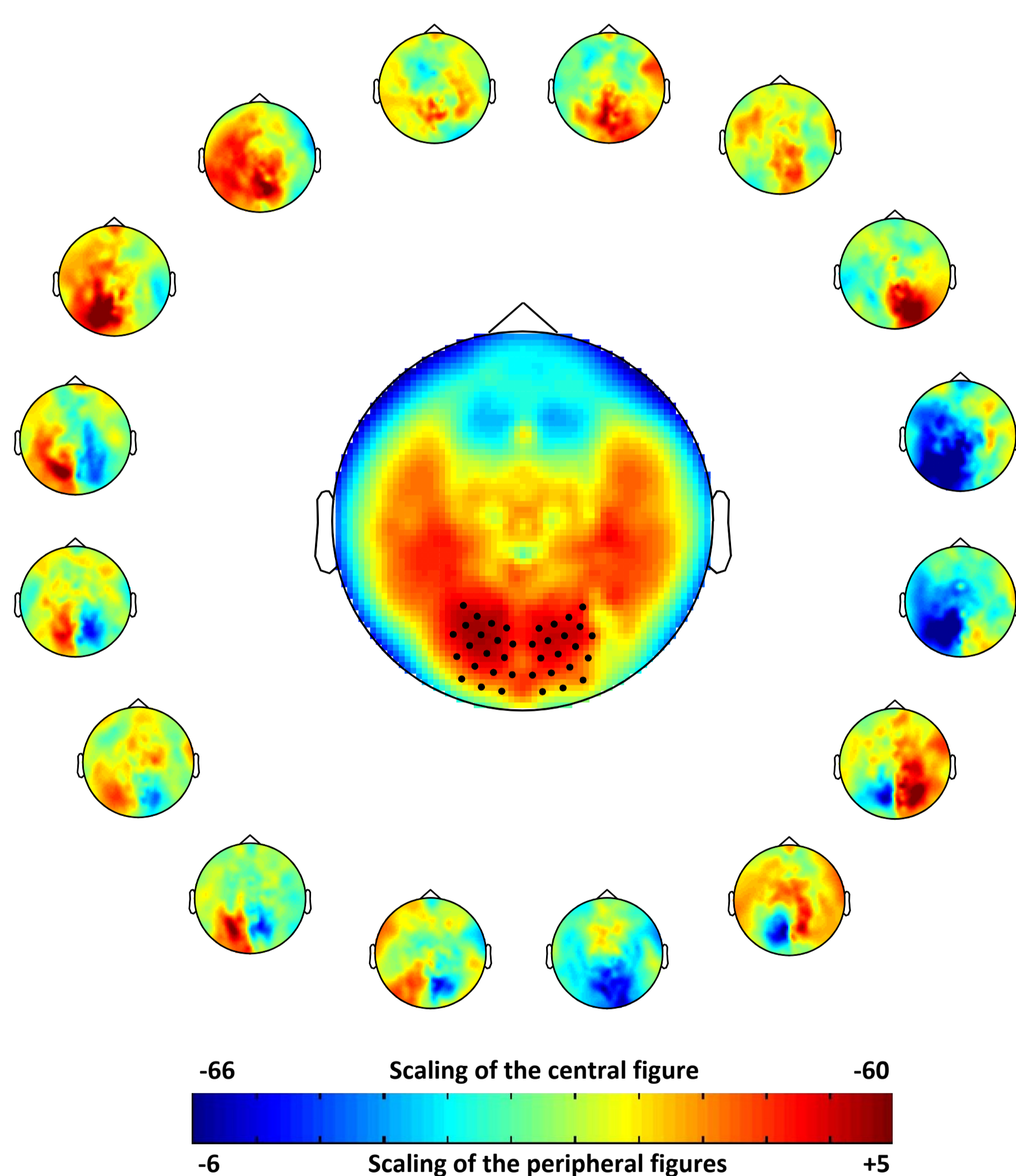
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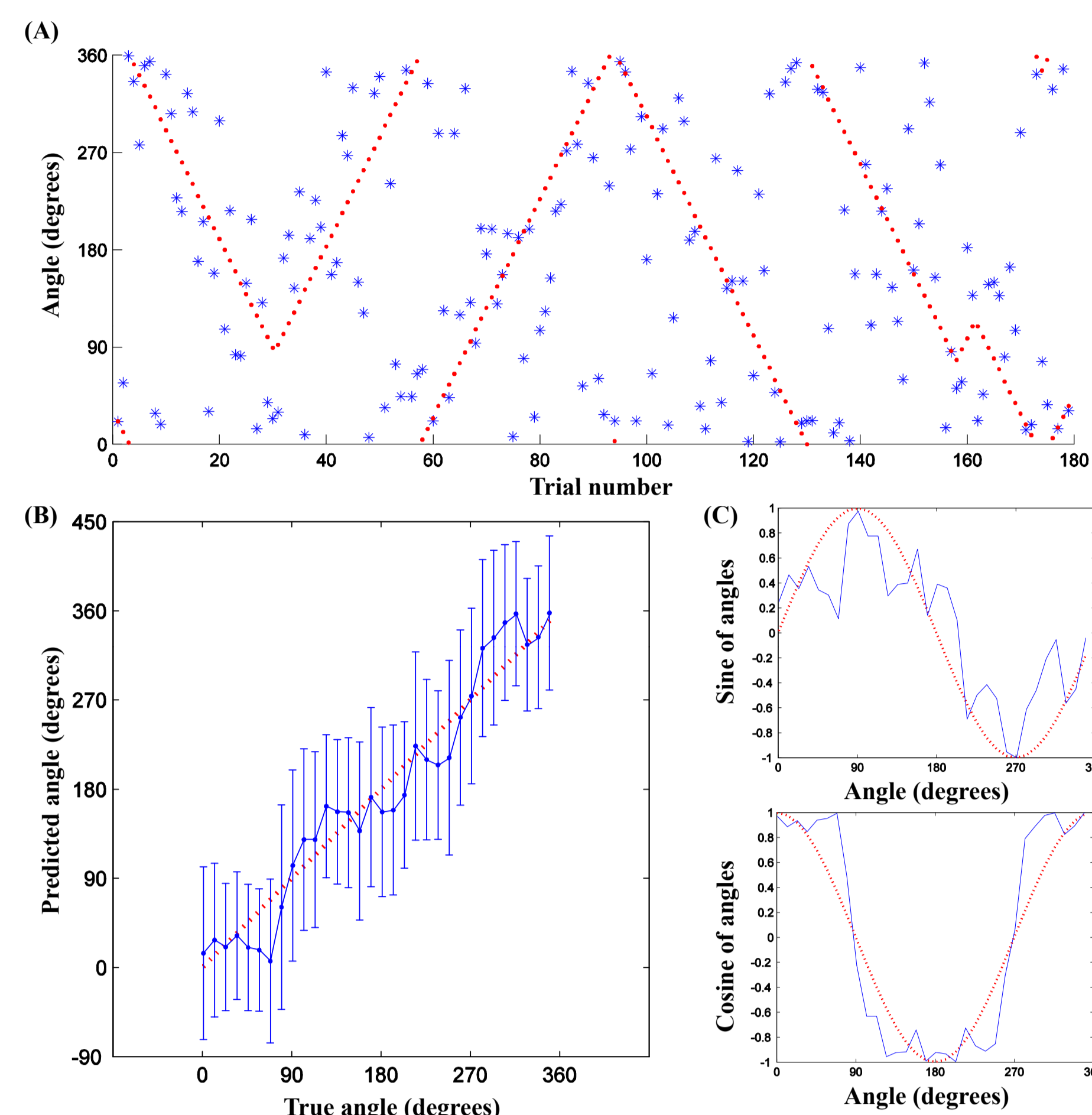
Introduction

Brain-computer interfaces clearly benefit from as many control signals as possible. We have here explored the possibility of using posterior alpha activity modulated by covert attention as a BCI control signal. Covert attention is the act of mentally focusing on a target without changing gaze. In an offline study, we show that modulations of posterior alpha activity can predict the direction to which a subject is covertly attending. Offline experiments have also shown that when attention is directed to the left visual hemifield, alpha activity decreases in the right posterior hemisphere while simultaneously increasing in the left hemisphere (and vice versa). Therefore, the ratio between left and right posterior alpha power, referred to as the ‘alpha lateralization index’, is strongly correlated with covert attention. We have developed an online brain-computer interface (BCI) system controlled by covert attention. The system is driven by the alpha lateralization index as computed from posterior MEG sensors. Online streaming and processing was done using FieldTrip (<http://fieldtrip.fcdonders.nl>).

Modulations of posterior alpha activity can predict the direction to which a subject is covertly attending.



The distribution of alpha power with respect to 16 divisions. The arrangement of the figures reflects the direction of covert attention which is clearly correlated with the spatial topography. The central figure shows the alpha power averaged over all directions and the black dots show the area of interest. Note that data is log-transformed prior to averaging.



Example from one subject. (A) The dotted line is the actual angle of the target and the stars show the predicted angle. Note the change of direction around four random time points. (B) The regression results applied to the full data for the same subject. Error bars show the standard deviation. (C) Sine and cosine components of the mean predicted angles.

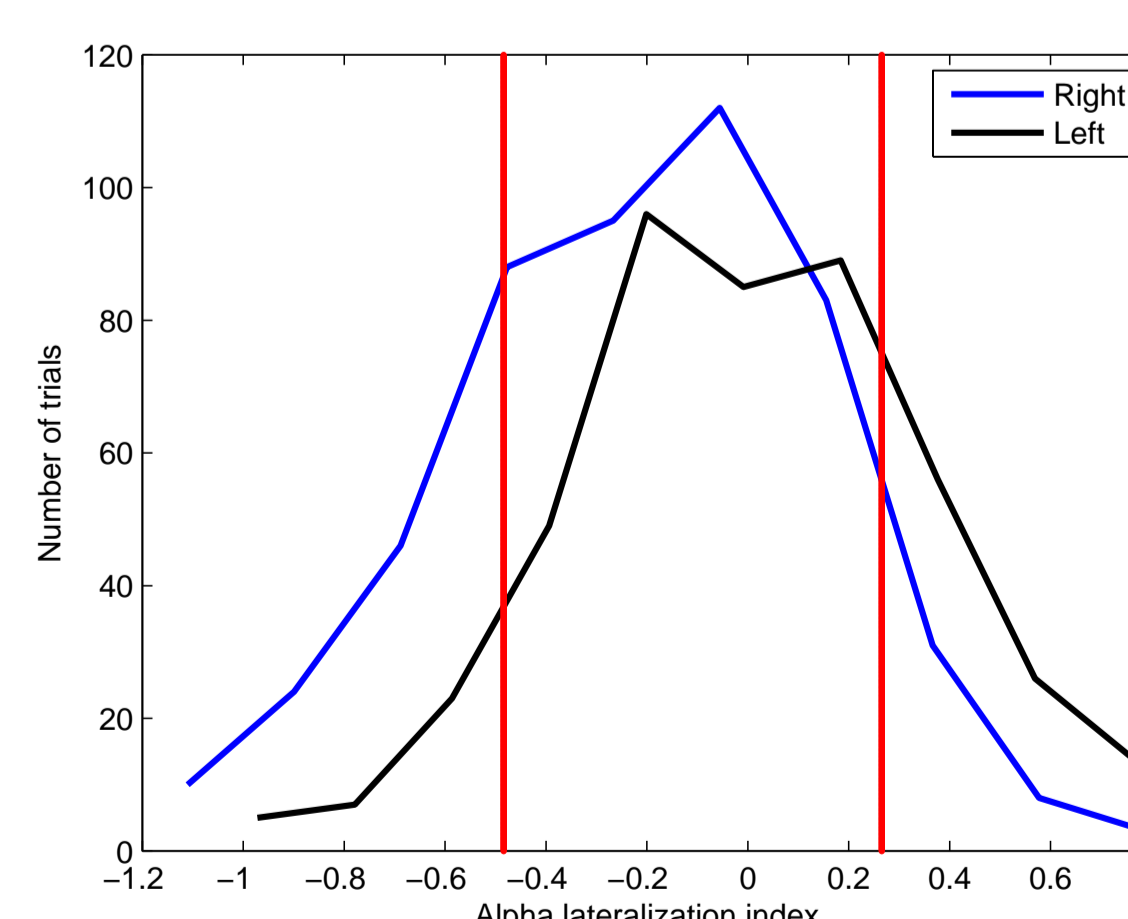
Covert attention used for one-dimensional BCI control



Two targets were presented on the right and left side of the screen. An arrow was presented to indicate the direction to which a subject should covertly attend.

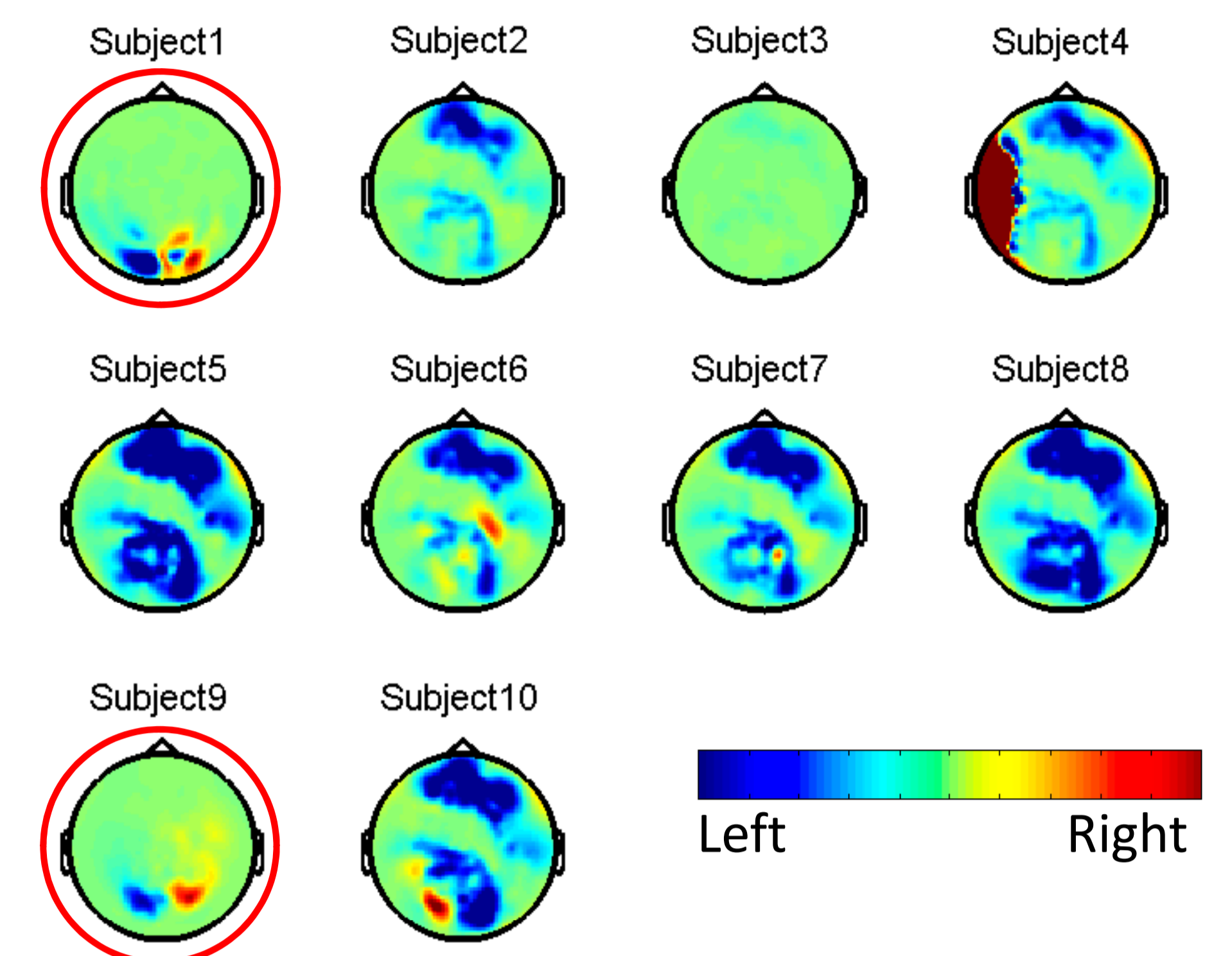


Subjects were asked to covertly attend to the target, while fixating in the middle. If the lateralization index indicated that the subject attended to the right, the feedback disc rotated clockwise, and vice versa when the subject attended to the left visual hemifield.



A histogram of the alpha lateralization index for left and right visual attention. In order to predict the attended direction, the mean \pm 1 SD of the alpha lateralization index was used. Values below the mean - 1 SD were classified as right covert attention while values above the mean + 1 SD were classified as left covert attention. The red lines show the threshold levels.

BCI based on covert attention succeeded in two subjects with strong alpha lateralization



Alpha difference in right - left attention. The distribution of the differences of alpha power over conditions when subjects attended to left and when they attended to right visual hemifield.

Subject	Performance	Subject	Performance
1	0.75	6	0.54
2	0.53	7	0.41
3	0.55	8	0.56
4	0.44	9	0.83
5	0.51	10	0.33

Subjects' performance during the task. The significant ones are shown in bold face. This result shows that the current paradigm only works for 2 out of 10 subjects, while the offline study showed that covert attention could be predicted for 7 out of 11 subjects. We believe that the current visual feedback causes subjects to lose the ability to direct their visual attention to the pre-specified direction and to attend to the central feedback disc instead. We are working on a new paradigm which does not introduce any interference between covert attention and visual feedback.

Future Work

Decoding the angle of attention in an online setup allows various new BCI applications such as:

- Brain Controlled Mouse.
- BCI Speller.
- Map Navigator.
- Brain Controlled Wheelchair.

References

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- [2] M. van Gerven and O. Jensen. Attention modulations of posterior alpha as a control signal for two-dimensional brain-computer interfaces. *J. Neurosci. Meth.*, 179(1):78–84, 2009.
- [3] M. van Gerven, A. Bahramisharif, T. Heskes, and O. Jensen. Selecting features for BCI control based on a covert spatial attention paradigm. *Neural Networks*, 22:1271–1277, 2009.