The sensitivity of SSVEPs to variations in numerical material for automatic Processing of Small magnitudes

Adrien Lorant, Anahita Basirat, Marine Coeugnet, Marion A. Vincent, Sandrine Mejias

The sensitivity of SSVEPs to variations in numerical material for automatic Processing of Small magnitudes

Lorant, A., Basirat, A., Coeugnet, M., Vincent, M.A. & Mejias, S.

Univ. Lille, CNRS, UMR 9193 - SCALab - Sciences Cognitives et Sciences Affectives, F-59000 Lille, France

* Corresponding author: sandrine.mejias@univ-lille.fr

Background

> Different animal species can access an accurate representation of small quantities [2].

> Most human cultures have invented ways to represent numerical quantities using codes.

> Educated adults have access to a numerical mental representation, whether numbers are conveyed by :

Analogical displays ("non-symbolic")   Abstract numerals ("symbolic")

> In the field of numerical cognition, the Fast Periodic Visual Stimulation-EEG method (FPVS) has already been tested with various types of numerical content, such as dots [3,4], fingers [1,4] and Arabic digits [4]. Additionally, it is a powerful tool for studying numerical processing that does not require an explicit task (no behaviour) and requiring a small number of trials (fast) with very limited exclusion of participants (efficient).
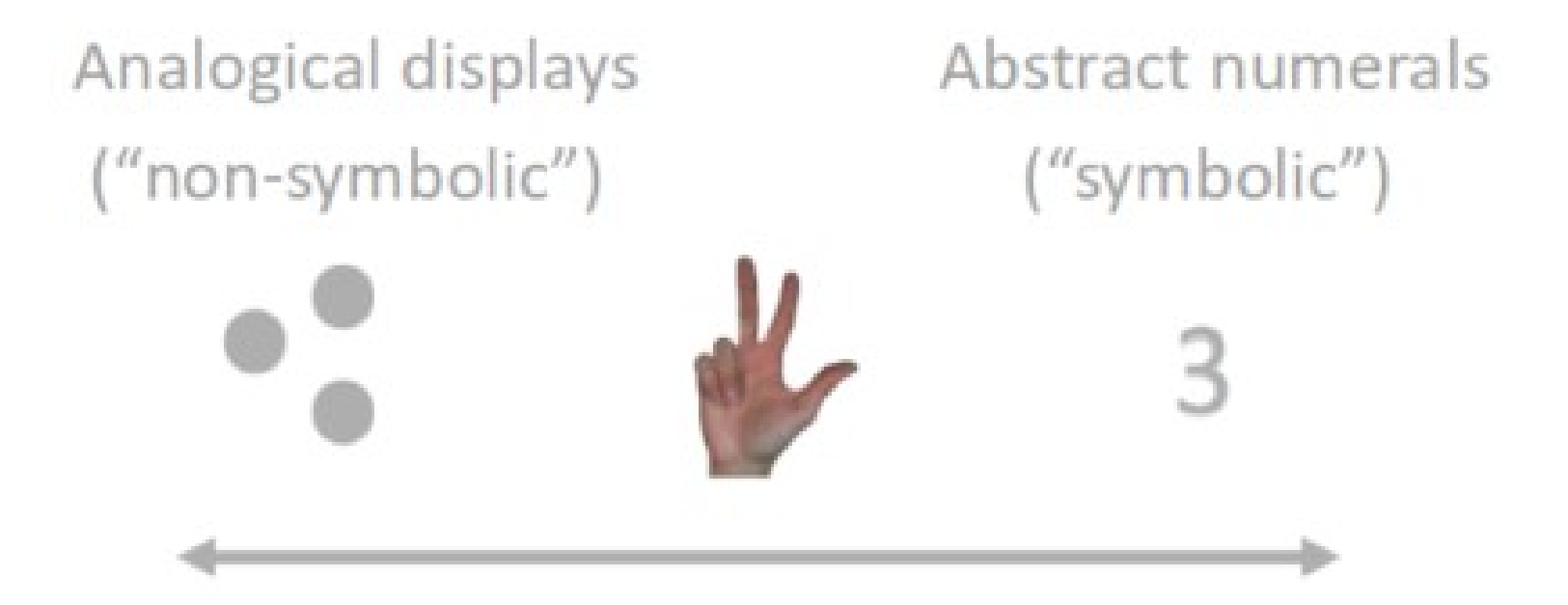
Aim : Our primary objective was to ascertain the sensitivity of steady-state visual evoked potentials (SSVEPs) to subtle (small) numerical magnitude variations, mediated by specific types of numerical materials (dots, fingers, Arabic digits).
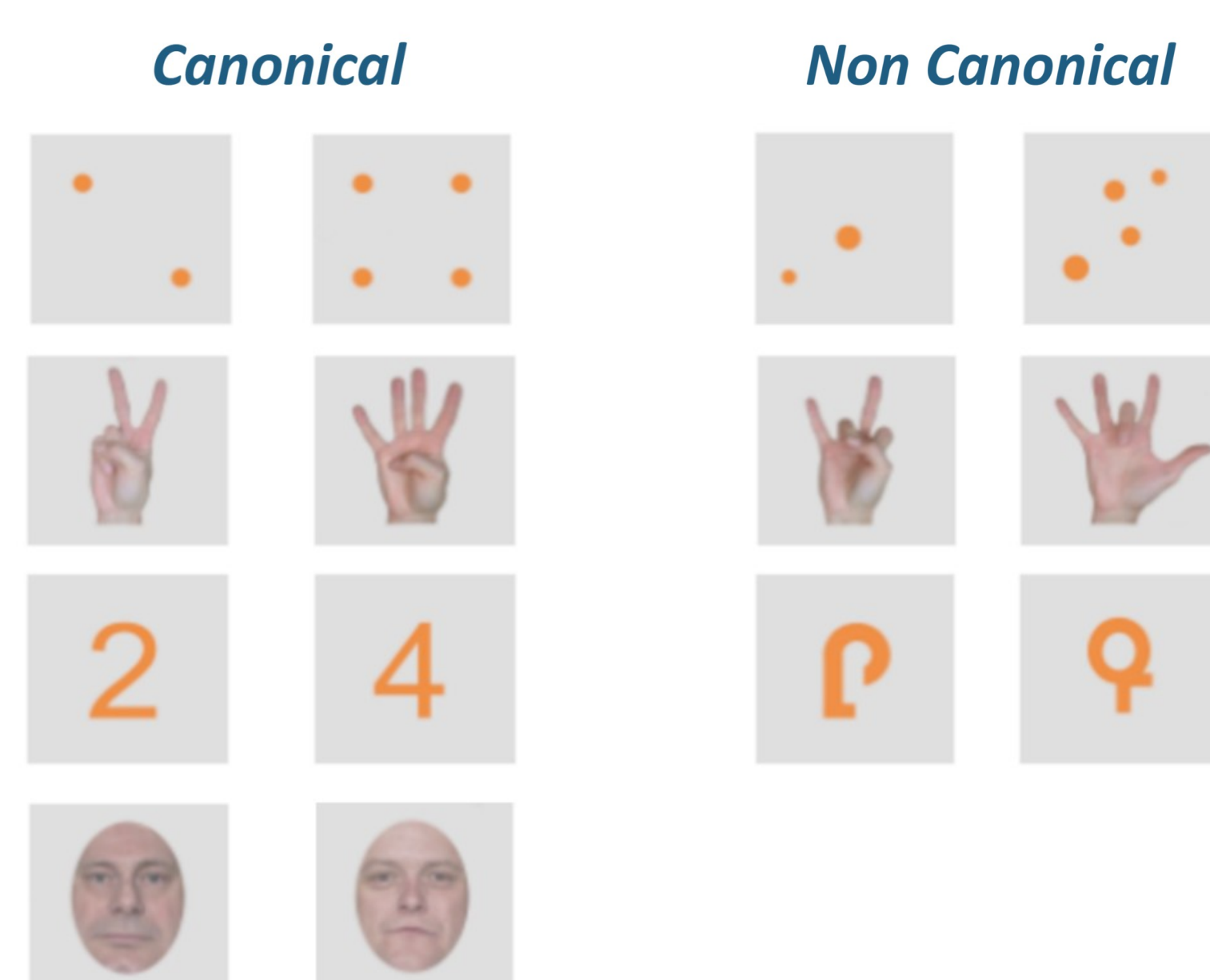
Methods

> **Participants** : **14** students (mean age = **22.714** y.o.) from Lille University were recruited. All participants were female, and all of them were right-handed.

> **Material** : EEG - 64 channels Biosemi system

> **Stimuli** :

Canonical   *Non Canonical*

> Dots

> Fingers

> Arabic digits

> Control : faces

The numerical stimuli **«2»** (in various formats) were presented at a frequency base-rate of 6.25 Hz, with oddball items **«4»** inserted every fifth item (i.e., 6.25/5 = 1.25Hz).

> **Procedure** : Each trial consisted in a 40-s random stimulation sequence surrounded by 2-s fade-in and fade-out periods. The baseline condition consisted of the presentation of **«2»** only. In the oddball experimental condition, **«2»** and **«4»** was compared.
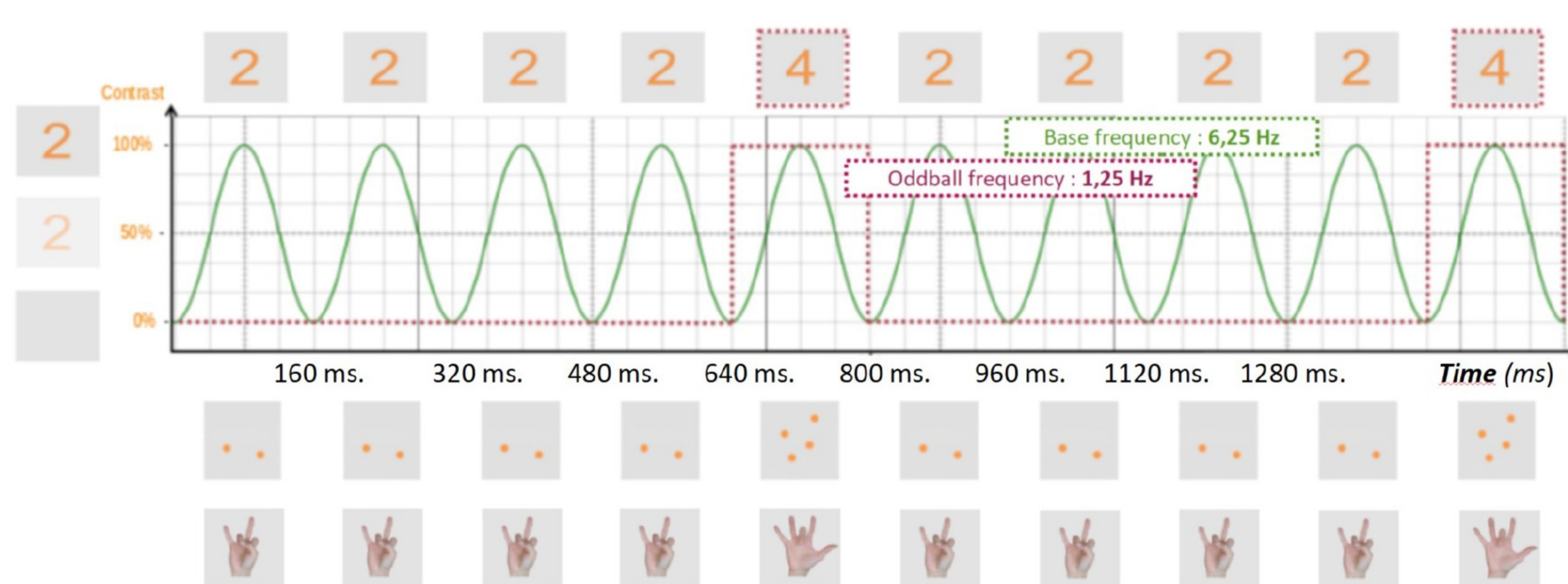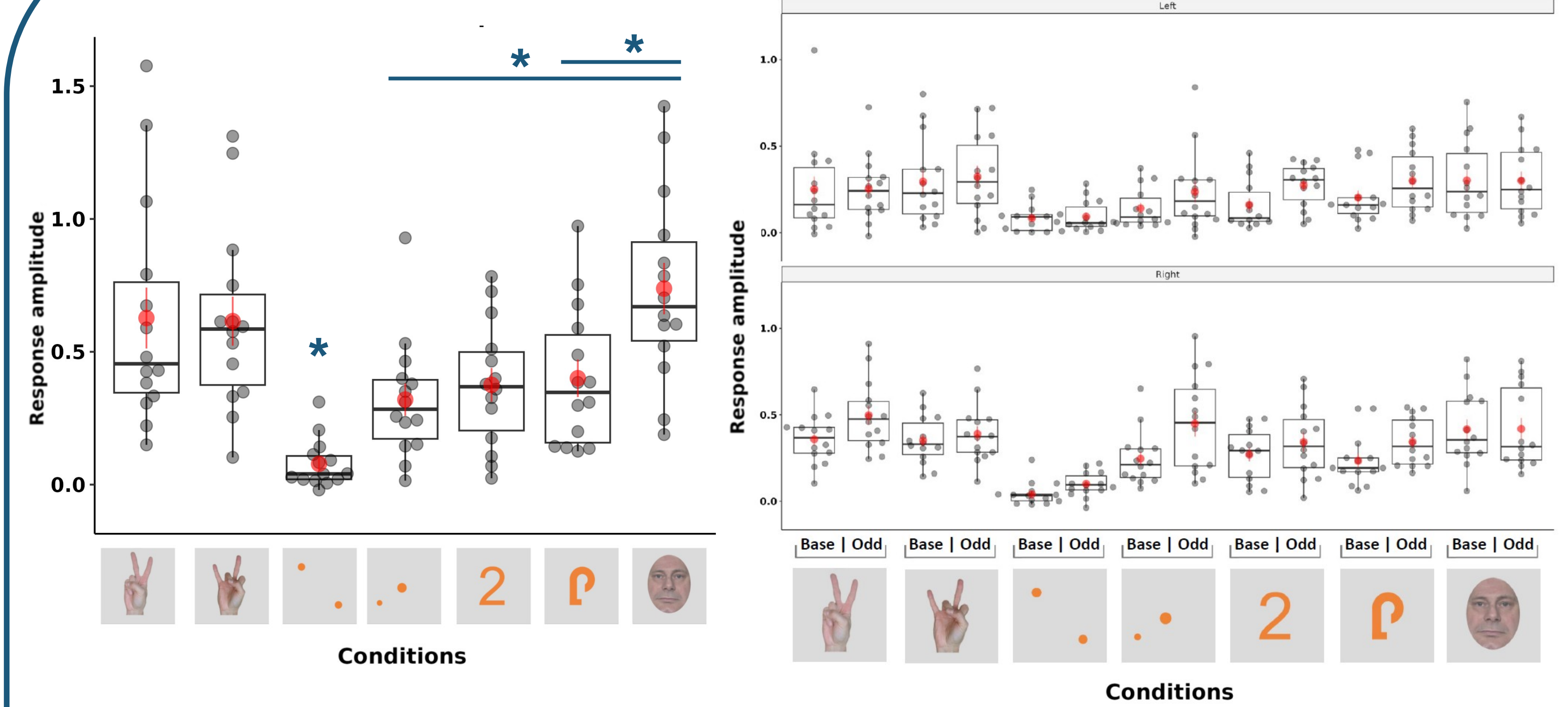

Results

Fig.1 : Base condition (middle occipital electrodes) - Averaged baseline subtracted SSVEP at the 6.25Hz base-rate over the middle occipital electrodes including Oz for all conditions without oddball.

Fig. 2 : Averaged baseline subtracted SSVEP at the 6.25Hz base-rate over left and right electrodes for all stimuli types in two conditions: conditions without oddball (Base) and conditions with oddball (Odd) (ROI Left : 'P3', 'P5', 'P7', 'PO7', 'PO3' and ROI Right : 'P4', 'P6', 'P8', 'PO8', 'PO4').
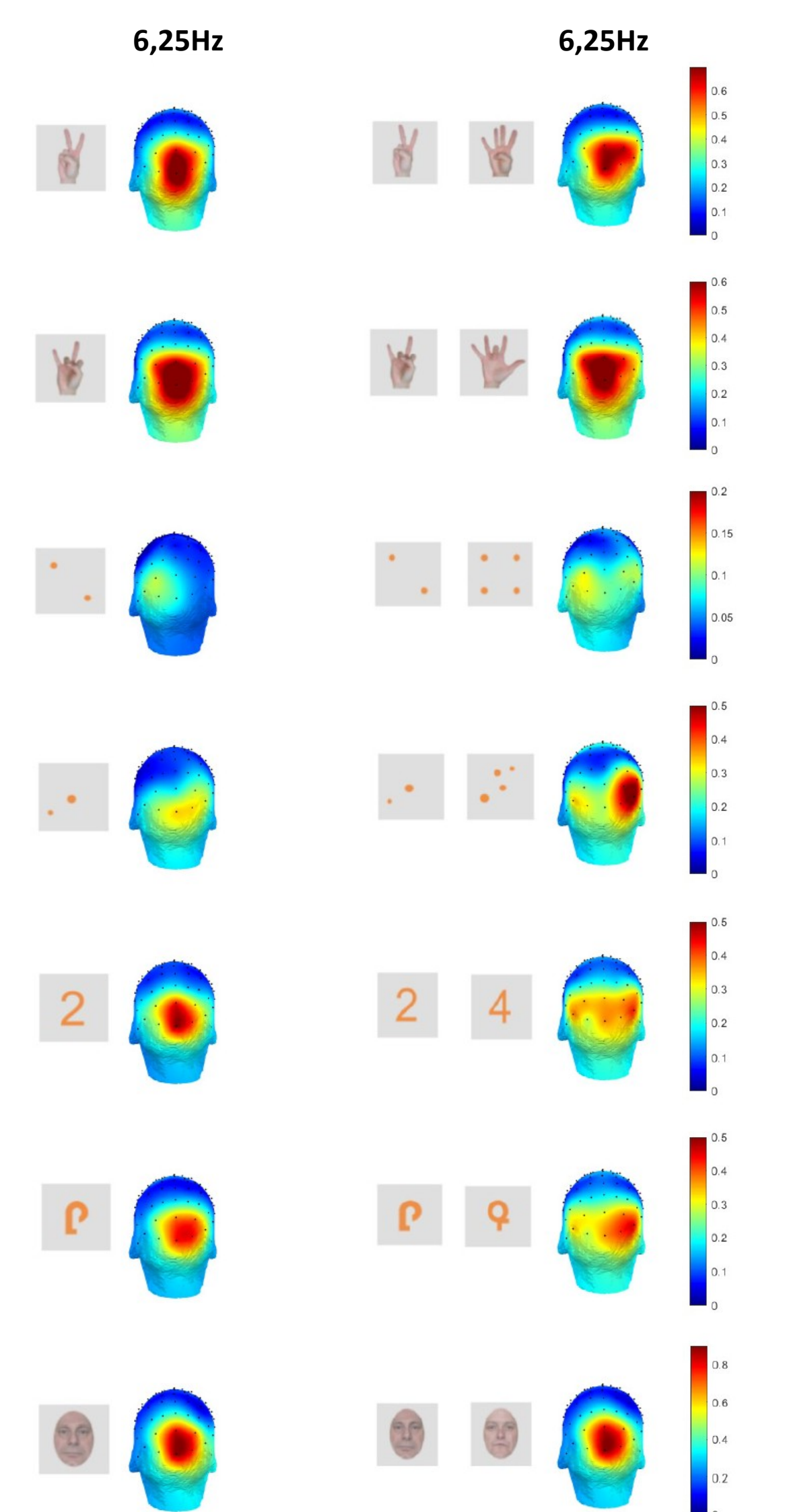

Fig. 3 : Topography maps of baseline subtracted SSVEP at the 6.25Hz base-rate for all stimuli types in two conditions : conditions without oddball (left) and conditions with oddball (right).
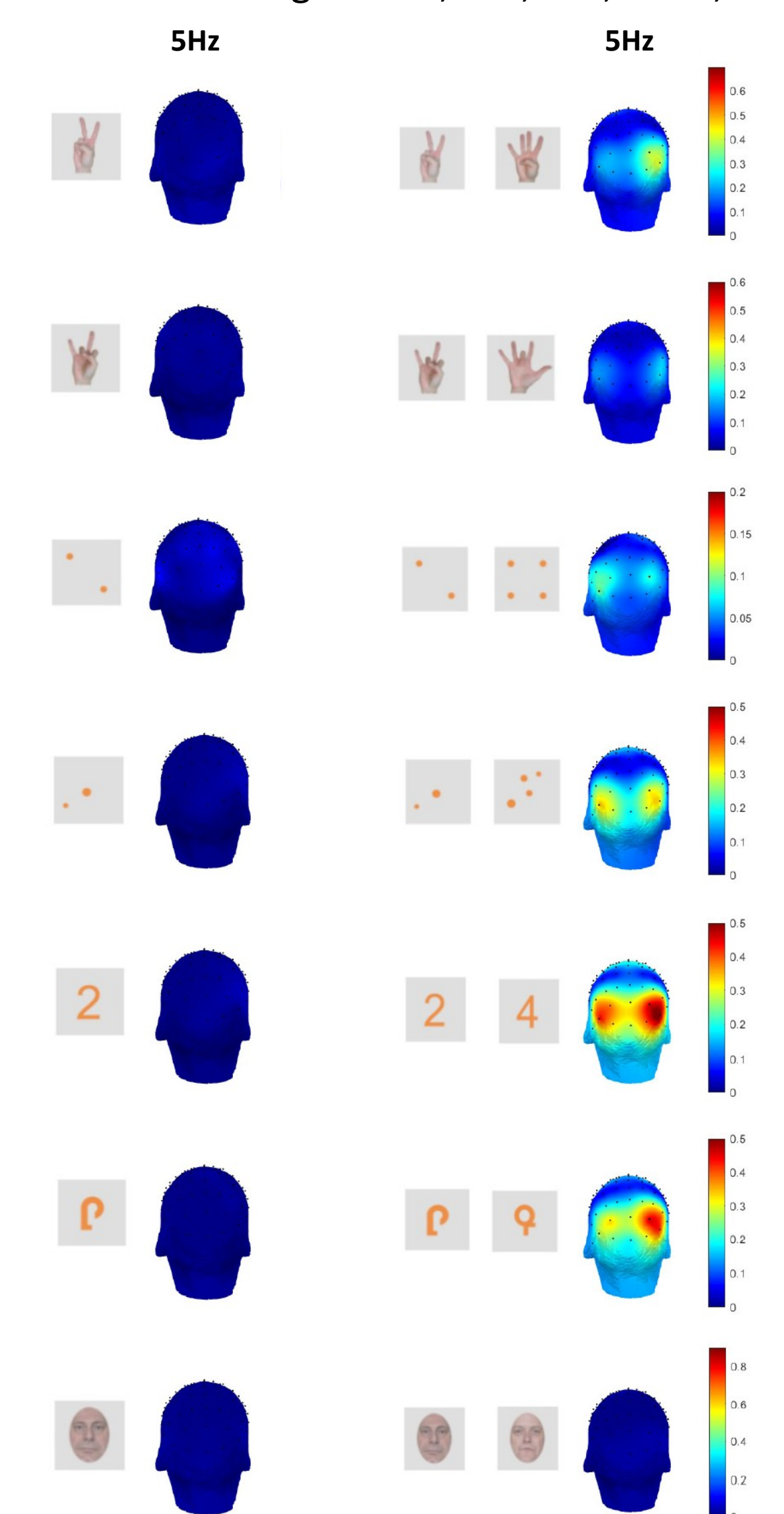
Fig. 4 : Topography maps of baseline subtracted SSVEP at 5Hz (3rd harmonic) for all stimuli types in two conditions: conditions without oddball (left) and conditions with oddball (right).

References

• [1] Buyle, M., Lochy, A., Vencato, V., & Crollen, V. (2023). Stronger neural response to canonical finger-number configurations in deaf compared to hearing adults revealed by FPVS-EEG. Human Brain Mapping, 44(9), 3555–3567.

• [2] Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. Trends in Cognitive Sciences, 8(7), 307-314.

• [3] Guillaume, M., Mejias, S., Rossion, B., Dzhelyova, M., & Schiltz, C. (2018). A rapid, objective and implicit measure of visual quantity discrimination. Neuropsychologia, 111, 180-189.

• [4] Marlair, C., Crollen, V., & Lochy, A. (2022). A shared numerical magnitude representation evidenced by the distance effect in frequency-tagging EEG. Scientific Reports, 12(1), Article 1.

Conclusions

Using an oddball FPVS paradigm, we demonstrated that SSVEPs were modulated by the nature of the stimuli.

• In conditions without oddball, response amplitudes were greater for biological stimuli (fingers and faces) compared to non-biological ones, and significantly smaller for canonical dots. This suggests that the 6.25Hz base-rate may not *always* be the most appropriate frequency.

• Oddball SSVEPs emerged at a frequency of 1.25Hz (and its harmonics) for each numerical content (not for faces and non-canonical fingers), indicating the ability to discriminate small numerical changes.

• Finally, neural responses exhibited distinct characteristics based on the type of material presented, with responses being significantly larger in the right ROI for analogical stimuli (dots, fingers) and in the left ROI for Arabic digits (false Arabic digits had bilateral activation).

SCAN ME