A multi-modal fNIRS/EEG investigation of the fronto-parietal network during audio-visual matching

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INTRODUCTION

The neural substrates of visual attention are known to be rooted in the fronto-parietal circuitry [1], and both frontal and parietal cortices have been hypothesized to play a crucial role in cross-modal matching of audio-visual information. Here we investigated the interplay between frontal and parietal regions both at the electrical and hemodynamic level using a cross-modal matching task. A multi-modal fNIRS/EEG acquisition was performed by simultaneously acquiring fNIRS and EEG data on adults.

MATERIALS AND METHODS

Participants: Sixteen healthy students (mean age=26±3, 8 F). Of these, 4 were discarded in the fNIRS analysis (fNIRS subgroup=12) while 7 in the EEG one (EEG subgroup=9).

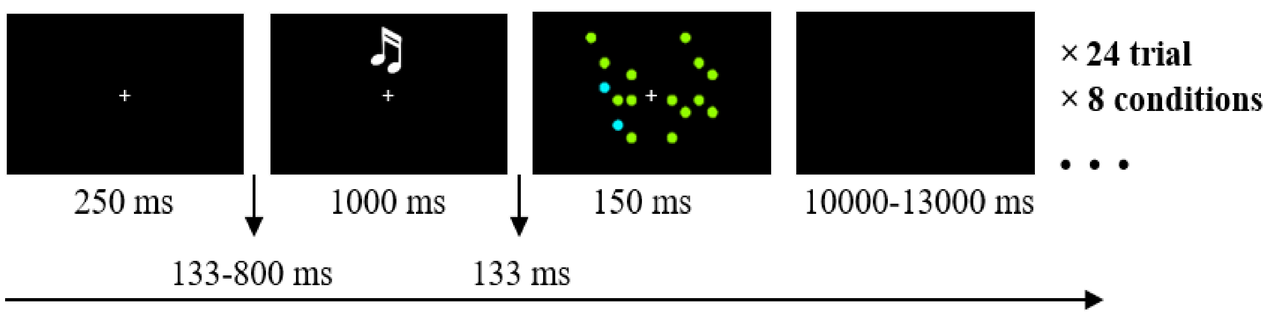

Fig. 1: Auditory stimuli consisted of either 2 or 3 beep sounds. The number of beeps was either congruent or incongruent with the number of subsequently presented lateralized visual targets (i.e. either 2 or 3 filled circles). Participants were required to orient covertly their attention to the lateralized visual targets whilst maintaining their gaze at fixation, under the requirement to press the 'yes' key when the number of beeps matched the number of lateralized visual targets, and 'no' when it did not.

Data acquisition: The bilateral fronto-parietal brain responses to the stimuli were monitored with an ISS Imagent™ system equipped with 8 detectors and 64 sources (36 channels at 3 cm and 2 short-separation (SS) channels, at 0.7 cm). Electroencephalographic data were recorded with a portable EEG system (Biopac®) with 8 channels.

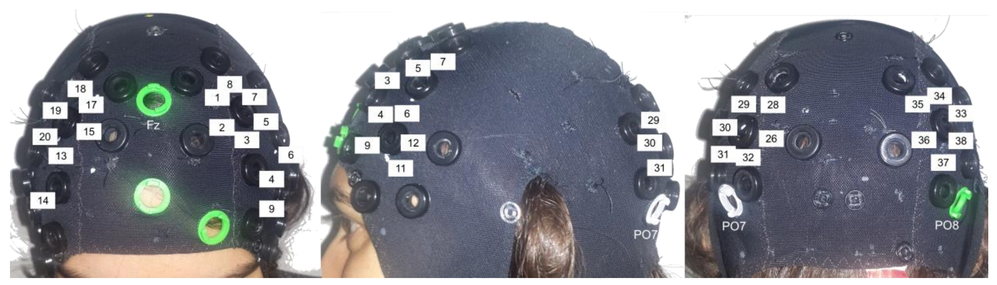

Fig. 2: Optode and electrode placement. Numbers correspond to fNIRS channels.

Data processing: **NIRS** data were analyzed with the Homer2 package [2]. Channels with very low intensity were pruned, motion artifacts were identified and corrected applying spline interpolation, and a band-pass filter (0.01-0.5 Hz) was applied. The hemodynamic response was recovered with a GLM approach, simultaneously regressing the SS signals to reduce physiological noise [3]. Only trials associated with correct responses were kept in the analyses. **EEG** data were offline re-referenced to the average of right and left ears, low-pass filtered (30 Hz) and a notch filter was applied (50 Hz). N2pc was computed at PO7 and PO8 (for each numerosity and audio-visual matching condition) as the difference between neural activity in the contralateral hemisphere to the lateralized targets (presented at either right or left hemifield) minus the ipsilateral activity. Only trials associated with correct responses and not contaminated by eye-movements were kept in the analyses.

RESULTS AND DISCUSSION

	2		3	
Congruent	ACC: 0.93(±0.1)	RT: 548(±156)	ACC: 0.95(±0.1)	RT: 543(±144)
Incongruent	ACC: 0.91(±0.1)	RT: 597(±159)	ACC: 0.91(±0.1)	RT: 601(±151)

Behavioral results. ACC = accuracy; RT = reaction times (ms). 2 (numerosity) × 2 (congruency) × 2 (hemifield) ANOVA revealed a main effect of congruency on RTs ($F(1,15)=28.5$, $p < .001$). Same statistical results were obtained when RTs were analyzed within the fNIRS and EEG subgroups.

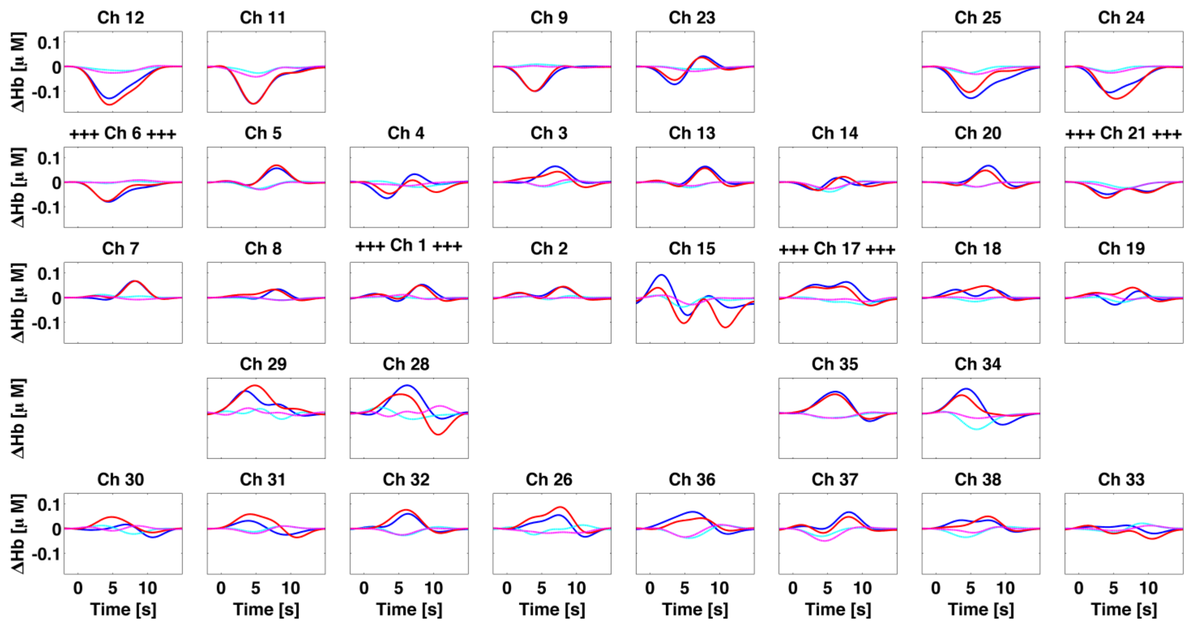

Fig. 4: Grand-average hemodynamic responses for the congruent (blue and cyan for HbO and HbR respectively) and incongruent (red and magenta for HbO and HbR respectively) conditions. +++ identifies channels showing a main effect for congruency in the 2 (numerosity) × 2 (congruency) × 2 (hemifield) × 2 (hemisphere) ANOVA (min $F(1,11) = 5.03$, ps < .046).

Results: 2 (numerosity) × 2 (congruency) × 2 (hemifield) ×2 (hemisphere) ×17 (channel) ANOVA revealed:

- Main effect of numerosity ($F(1,11) = 6.01$, $p = .032$)
- Main effect of channel ($F(16,176) = 3.80$, $p < .001$)
- Numerosity * channel ($F(16,176) = 2.31$, $p = .004$)
- Numerosity * congruency * channel ($F(16,176) = 1.82$, $p = .032$)
- Hemisphere * channel ($F(16,176) = 1.85$, $p = .028$)

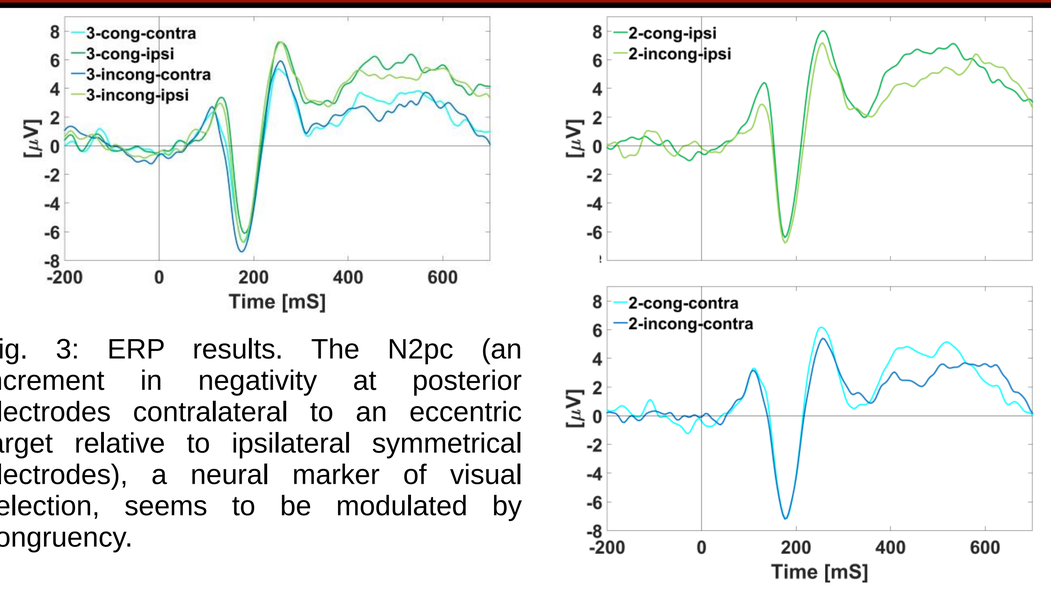

Fig. 3: ERP results. The N2pc (an increment in negativity at posterior electrodes contralateral to an eccentric target relative to ipsilateral symmetrical electrodes), a neural marker of visual selection, seems to be modulated by congruency.

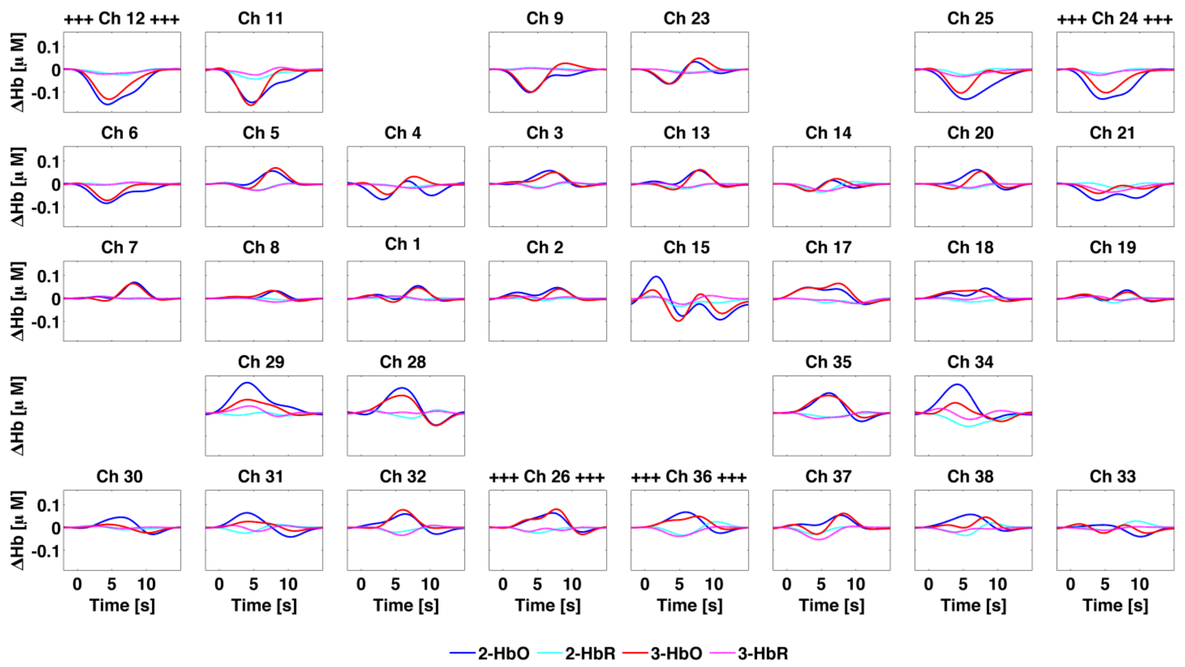

Fig. 5: Grand-average hemodynamic responses for numerosity 2 (blue and cyan for HbO and HbR respectively) and 3 (red and magenta for HbO and HbR respectively) conditions. +++ identifies channels showing a main effect for numerosity in the 2 (numerosity) × 2 (congruency) × 2 (hemifield) × 2 (hemisphere) ANOVA (min $F(1,11) = 7.90$, ps < .017).

The fNIRS results suggest the involvement of the frontal-parietal network in the task, with both numerosity and congruency playing a critical role. Results on a larger sample are required to better disentangle how these factors interact with each other and to better localize whether specific regions of the cortex are involved in the modulation of numerosity and/or congruency.

REFERENCES

[1] Corbetta et al., 2008. Neuron 58, 306-24. [2] Huppert et al., 2009. Appl Opt 48, D280-98. [3] Barker et al., 2013. Biomed. Optics Express 4 1366-79.

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