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Decoding Neuronal Activity

Matran-Fernandez A, Poli R (2017) **Towards the automated localisation of targets in rapid image-sifting by collaborative brain-computer interfaces.** *PLoS ONE 12(5): e0178498. https://doi.org/10.1371/journal.pone.0178498*

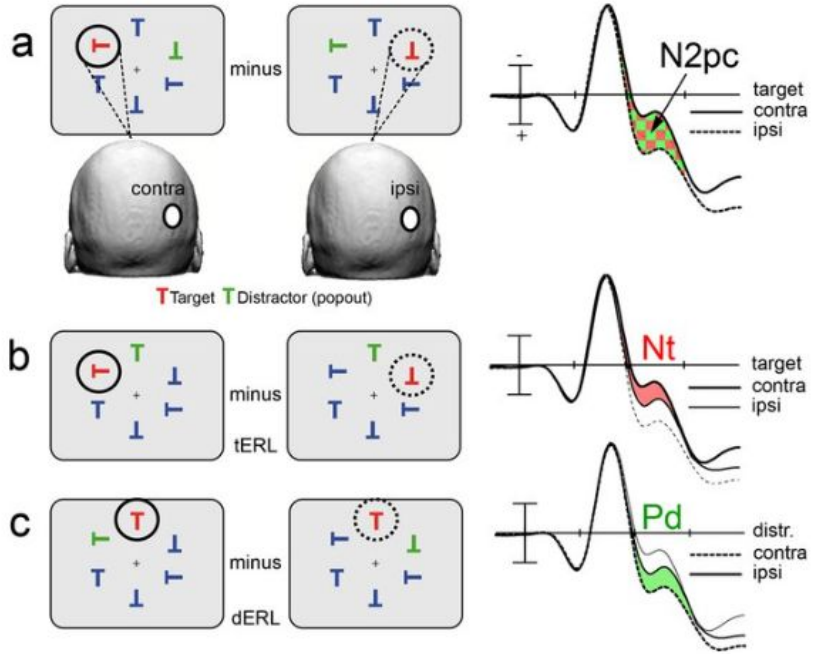
BCI for Automated Target Localisation

N2pc is an ***Event Related Potential (ERP)** component that indicates selective attention

It is lateralized (stronger in the hemisphere opposite to where the target is located) from the shape of the N2pc one can infer whether the target is left or right of the visual field

BCI could be used to make target localisation faster or even automated

➔ Prioritizing or separating images in order to quickly detect target images among distractors.



*ERP (Event-Related Potential) is the electrical activity of the brain measured in response to specific events or stimuli.

Experimental Design

24 “bursts” of 100 images presented at 5/6/10 Hz
each burst contains 10 targets

11 volunteers with normal or corrected-to-normal vision

- ➔ Ages ranging between 19 ± 33 years, mean age ± standard deviation = 24.3 ± 3.7 years old,
- ➔ 4 females,
- ➔ 5 left-handed

(A)
Target

(B)
Distractor

★ mentally count the number of airplanes they saw in each burst,

★ verbally report the count of that burst at the end.

EEG Preprocessing

EEG Data

64 ear-referenced channels, sample rate 2048 Hz

Filtering

band-pass filtering from 0.15–28 Hz

Downsampling

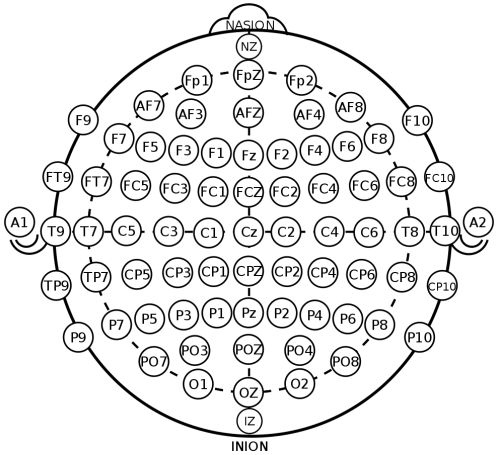
64 Hz

Eye Blinks & Movement

removal based on correlation algorithm

Epoch Extraction

time window **200-400ms** after picture onset



Due to the limited trials for left vs right classification and the risk of overfitting, only four electrode pairs (**PO7-PO8, P7-P8, PO3-PO4, O1-O2**) were used. The features from these pairs were combined, resulting in a feature vector of **56 elements for classification**.

ERP Analysis

Table 1. Average total plane counts reported by participants as a function of presentation rate.

	5 *Hz*	6 *Hz*	10 *Hz*
Average plane count	197.2	186.7	157.2
Sensitivity	82.2%	78.8%	65.5%

There were 240 airplanes in total in each level of difficulty.

https://doi.org/10.1371/journal.pone.0178498.t001

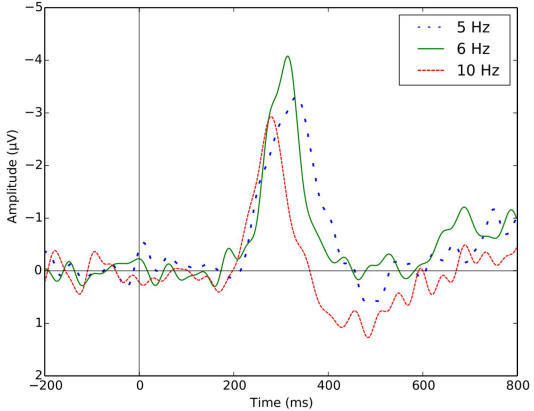
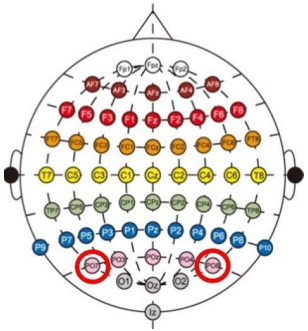


Fig 4. Grand-averaged difference plot of the contralateral minus the ipsilateral waveforms recorded at electrode sites PO7 and PO8 across lateral targets from the training set of one split.

https://doi.org/10.1371/journal.pone.0178498.g004



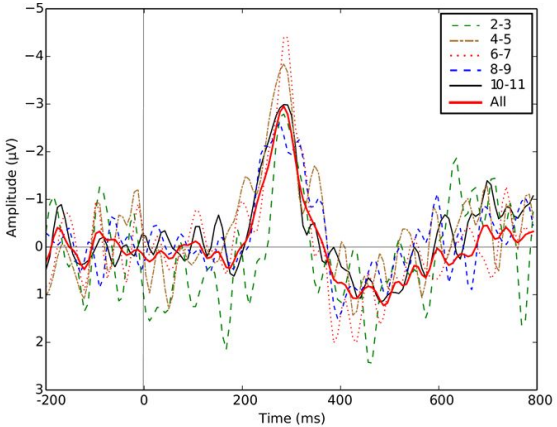


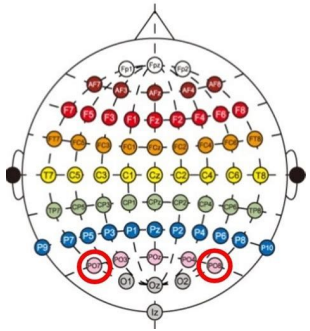
Fig 5. Grand-averaged contralateral minus ipsilateral waveforms recorded at PO7 and PO8 across all epochs from the training set of one split for a presentation rate of 10 Hz, separated depending on the distance (in number of images) to the previous target.

https://doi.org/10.1371/journal.pone.0178498.g005

The N2pc ERPs associated with well-separated targets (e.g., the line labelled as 10±11) **are not significantly bigger than** the N2pc's for poorly separated targets, i.e., line 2±3

ERP Analysis

- 59 targets were presented on the LVF; 85 on the RVF
- e.g. for the RVF, ipsilateral activity corresponds to electrode PO8, contralateral activity corresponds to PO7
- for the ERP, they plot the difference between the contralateral and the ipsilateral activity



ERP Analysis

→ latency of the N2pc tends to become shorter as the presentation rate increases

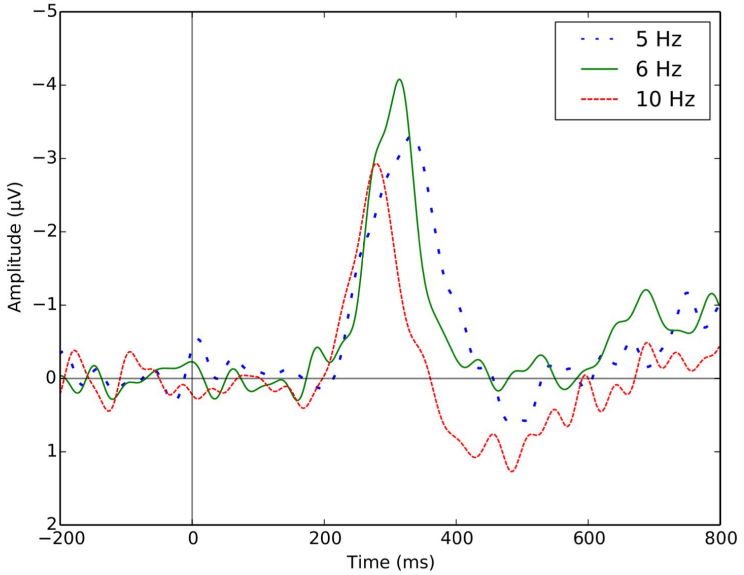
→ the peak amplitude at a presentation rate of 10 Hz is the smallest of the
three tested

Three possible hypothesis:

(1) target detection task is harder at high presentation rates

(2) higher presentation rate causes some targets to fall within a possible “refractory period” for the N2pc

(3) experimental design



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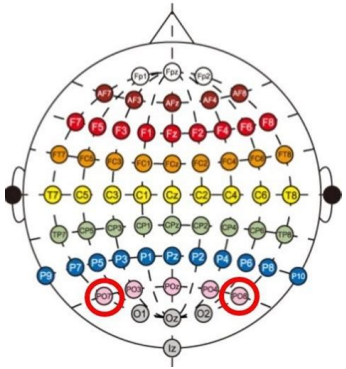


Results

→ single-user BCIs reasonably high, with performance for most participants being well above that of a random classifier (i.e., AUC = 0.5) and with the top quartile of our participants having AUCs >0.8

→ using simple methods for combining classifiers' outputs, we also found that collaborative BCIs significantly outperform single-user BCIs by up to 21%

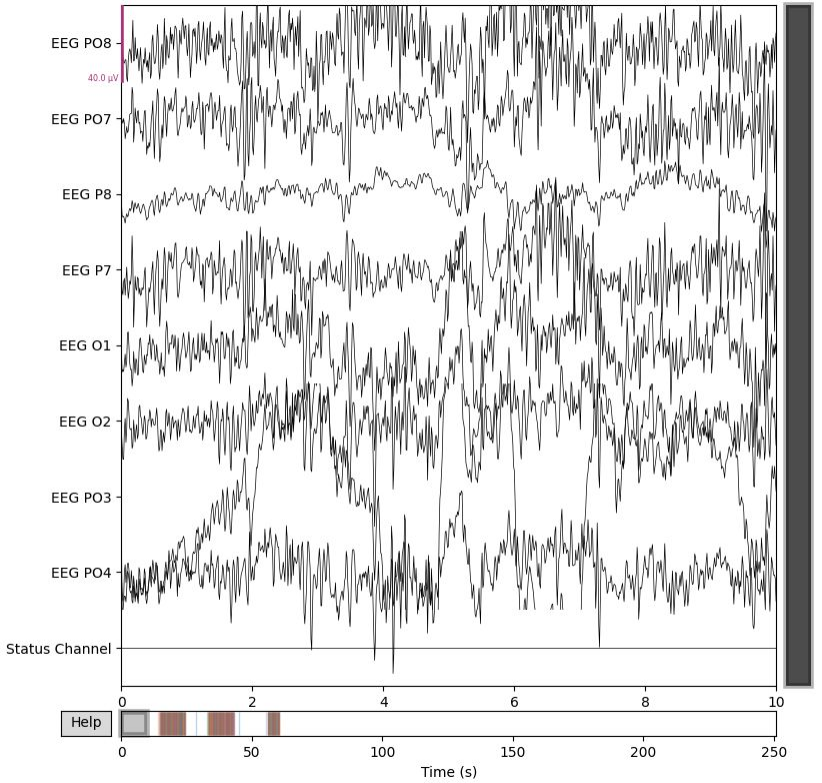
→ this happens even when no group-member selection is applied, performance increases dramatically when only participants with relatively similar performance are used to form a group

Practical Part

1. Importing and Inspecting: Raw data

```
Extracting EDF parameters from /content/physionet.org/files/ltrsvp/1.0.0/10-Hz/rsvp_10Hz_02a
EDF file detected
Setting channel info structure...
Creating raw.info structure...
<ipython-input-10-40f5bf3860ac>:3: RuntimeWarning: Channels contain different highpass filte
  raw_data = mne.io.read_raw_edf(edf_file, preload=True)
<ipython-input-10-40f5bf3860ac>:3: RuntimeWarning: Channels contain different lowpass filter
  raw_data = mne.io.read_raw_edf(edf_file, preload=True)
Reading 0 ... 514047  =      0.000 ...   251.000 secs...
<Info | 8 non-empty values
 bads: []
 ch_names: EEG PO8, EEG PO7, EEG P8, EEG P7, EEG O1, EEG O2, EEG PO3, EEG ...
 chs: 9 EEG
 custom_ref_applied: False
 highpass: 0.1 Hz
 lowpass: 28.0 Hz
 meas_date: 2013-02-06 23:27:16 UTC
 nchan: 9
 projs: []
 sfreq: 2048.0 Hz
 subject_info: 3 items (dict)
```

was already filtered, downsampled to 64 Hz & artefacts were already removed



1. Importing and Inspecting: Annotations

```
# Convert annotations to a DataFrame
annotations = raw_data.annotations
annotations_df = annotations.to_data_frame()

# Display the DataFrame
display(annotations_df)
```

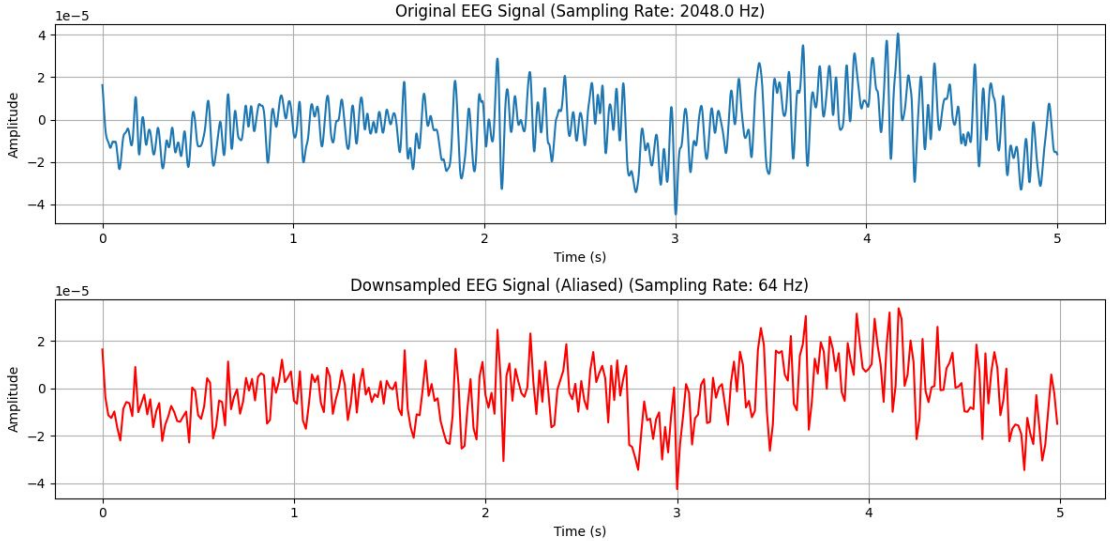
	onset	duration	description
0	2013-02-06 23:27:30.103000	0.0	RSVP_burstSize=100_block=0_frame rate=6
1	2013-02-06 23:27:30.612300	0.0	T=0,x=-1
2	2013-02-06 23:27:30.716300	0.0	T=0,x=-1
3	2013-02-06 23:27:30.815400	0.0	T=1,x=259
4	2013-02-06 23:27:30.915500	0.0	T=0,x=-1
...	...	...	...
246	2013-02-06 23:28:16.163000	0.0	T=0,x=-1
247	2013-02-06 23:28:16.263600	0.0	T=1,x=366
248	2013-02-06 23:28:16.363200	0.0	T=0,x=-1
249	2013-02-06 23:28:16.462800	0.0	T=0,x=-1
250	2013-02-06 23:28:16.560500	0.0	T=0,x=-1

251 rows × 3 columns

T = 1 target
T = 0 distractor

x is the location of the target in pixel

2. Downsampling



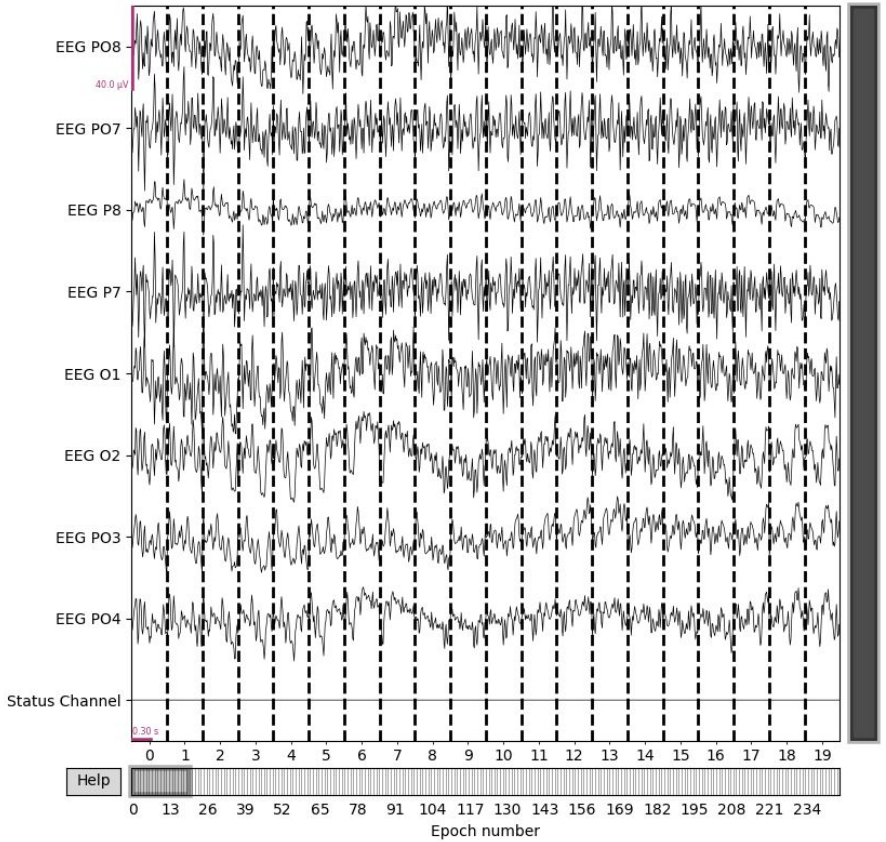
3. Epoching

I. choosing time intervals and baseline

```
# Define epoching parameters
tmin = -0.2  # 200 ms before stimulus
tmax = 0.4   # 400 ms after stimulus
baseline = (-0.2, 0)  # Baseline from -200 ms to 0 ms
```

II. sorting epochs by “target appeared left or right”

```
if x_value < (center_pixel - pixel_threshold):
    left_targets.append(onset)

elif x_value > (center_pixel + pixel_threshold):
    right_targets.append(onset)
```

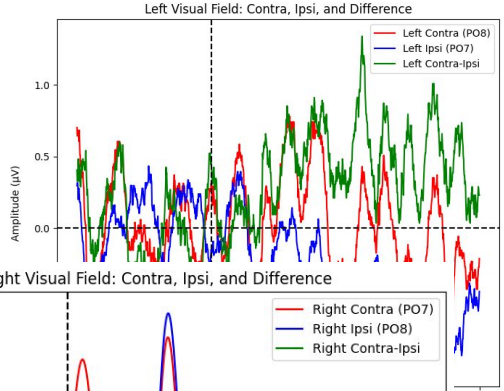


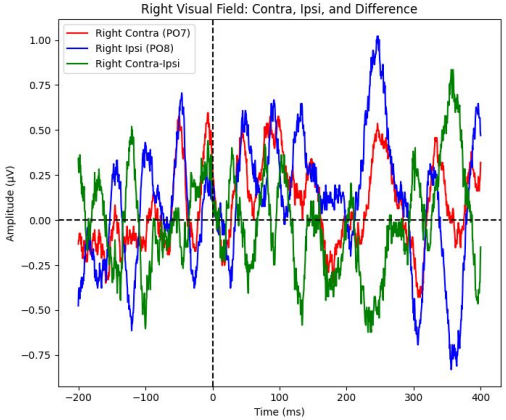
4. ERP Analysis

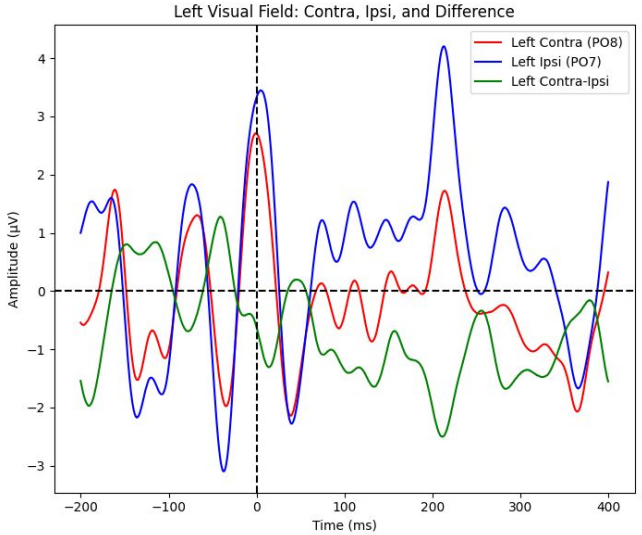
```
# Separate the epochs based on visual field
left_epochs = epochs['left_target']
right_epochs = epochs['right_target']

# Calculate the evoked responses
left_evoked = left_epochs.average()
right_evoked = right_epochs.average()

# Extract data from PO7 and PO8 electrodes
left_contra = left_evoked.copy().pick_channels(['EEG PO8']).data[0]
left_ipsi = left_evoked.copy().pick_channels(['EEG PO7']).data[0]
right_contra = right_evoked.copy().pick_channels(['EEG PO7']).data[0]
right_ipsi = right_evoked.copy().pick_channels(['EEG PO8']).data[0]

# Calculate the difference waveforms (contralateral minus ipsilateral)
left_diff = left_contra - left_ipsi
right_diff = right_contra - right_ipsi
```

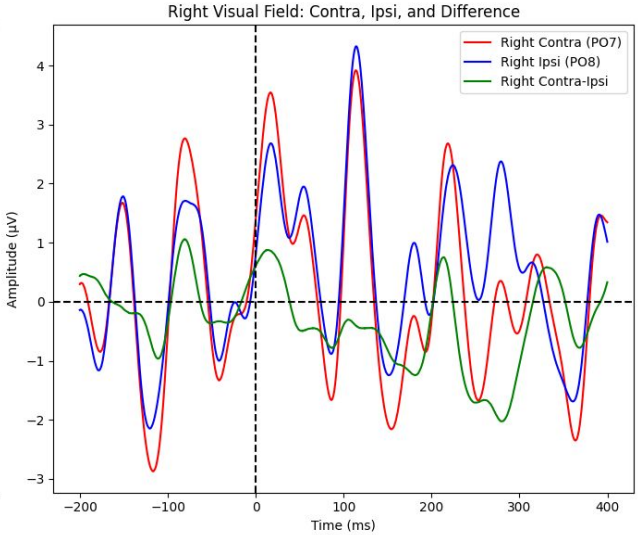
5. Results: Single Participant (10 Hz)

great differences between participants & side of VF



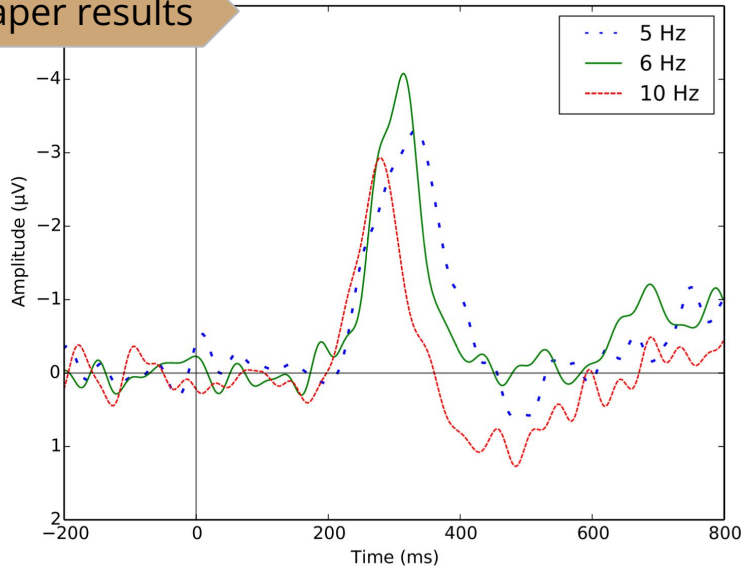






5. Results: Grand Average (10 Hz)

paper results



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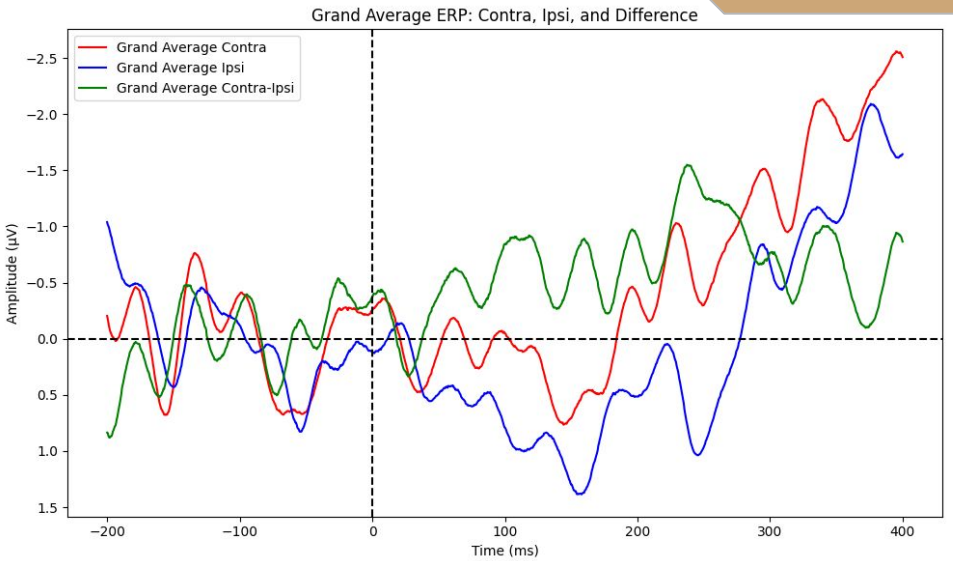
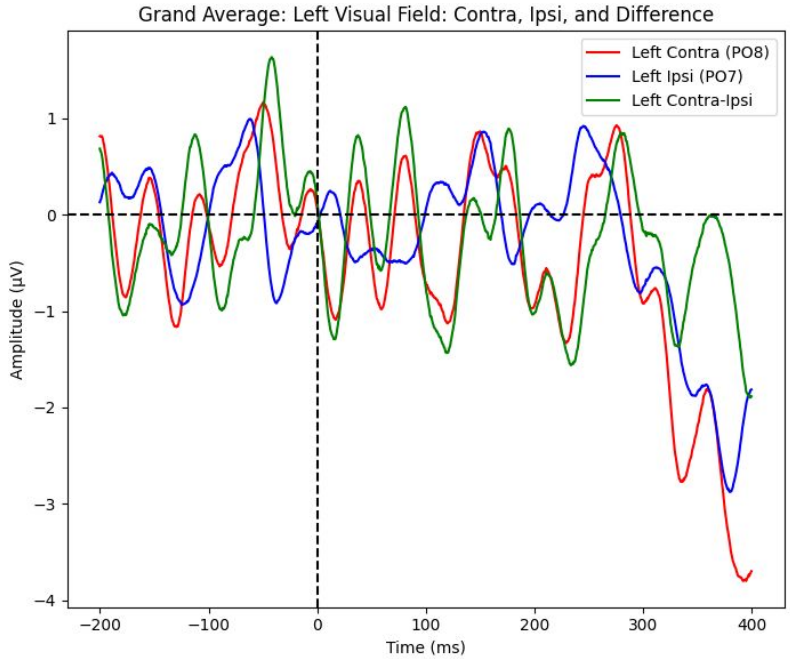
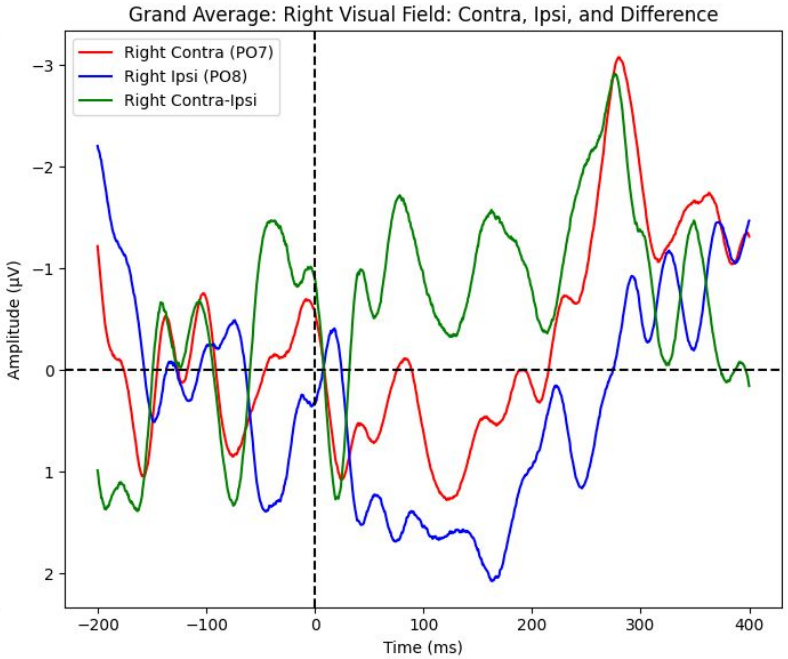
https://doi.org/10.1371/journal.pone.0178498.g004

our results



Grand Average grouped by LVF and RVF (10 Hz)





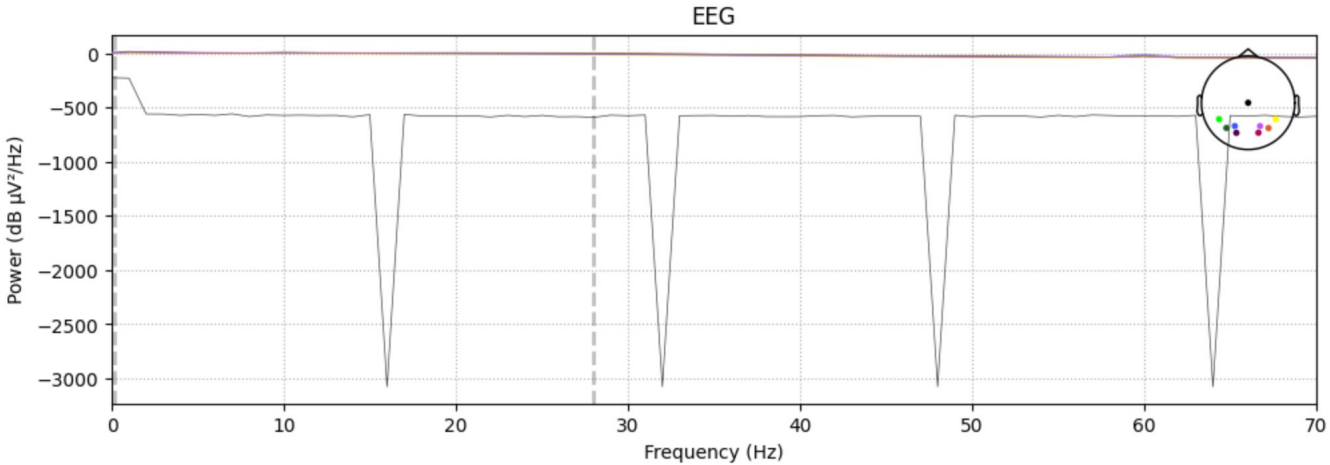
More results here: https://drive.google.com/file/d/1y61oPk4va-p62PzcEhZAS8XTIi3JzbCy/view?usp=sharing

Thank you!

your questions/comments...

Our Questions

What's wrong with our power density plot?

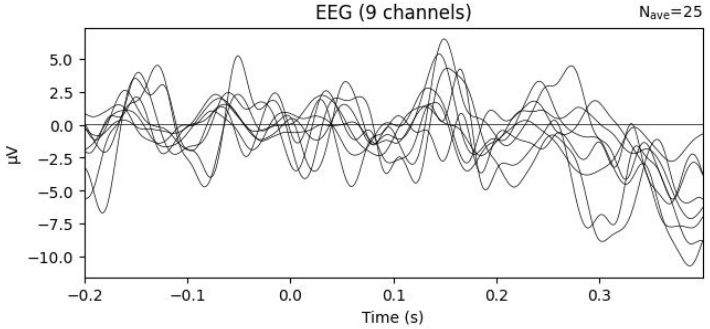


https://colab.research.google.com/drive/1e2iBHD_J2QyFbo3fYL8D_rmO6DmO7Z71?usp=sharing

Our Questions

ERP of target vs. distractor: Why the regularity?

target



distractor