Do EEG and Pupillometry Measures of Listening Effort Relate?

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Background

Pupil diameter is consistently related to listening effort mediated by changes in task difficulty [1], SNR [2], and speech intelligibility [3,4]. Listening effort across subjects has also been correlated to alpha power in a frontal brain source [5].

So far, however, in parietal EEG electrodes, alpha power and pupil diameter do not appear to be correlated, yet alpha power and effort are [3].

Hypotheses

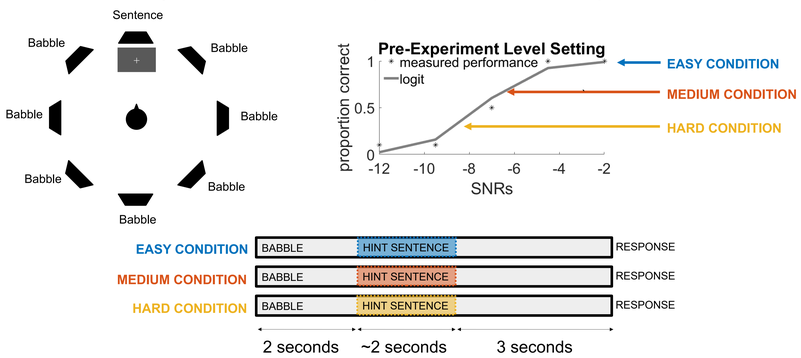
In parietal and frontal EEG source ROIs:

- Alpha power and effort will correlate
- Alpha power and pupil diameter will correlate

Methods

HINT Sentence Stimuli in Three conditions

- **Task:** Repeat HINT sentence after babble, then give rating of listening effort on 1-9 scale
- **Conditions:** Easy/Medium/Hard. 93 trials per condition, randomized presentation order



EEG and Pupillometry recorded simultaneously

- **Participants:** 16 NH participants, 9 female, 25.3 years old (SD 3.7). 1 excluded from analysis due to technical problems during data collection.
- **EEG:** 64 channel, BrainVision cap with Neuroscan SynAmps and Curry8 acquisition software
- **Pupillometry:** Pupil Lab glasses and recording software

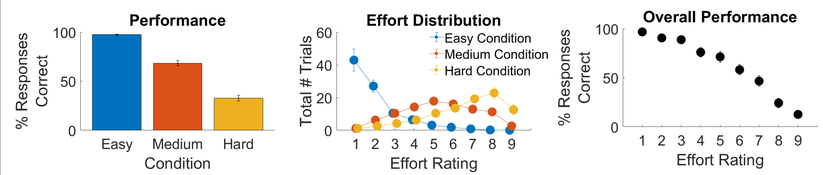
EEG and Pupil data cleaned and aligned

- **EEG:** Filtering and downsampling done in BVA. Ocular artifacts removed by ICA. Trials extracted from continuous data and further cleaned by visual inspection in FieldTrip.
- **Pupil Traces:** Diameter samples rejected if too large or small. All samples moved to time grid. 10 point smoothing. No interpolation. Trial rejection if > 50% data in trial was rejected.
- **Alignment:** Stimulus triggers in EEG aligned with audio recordings in pupil data

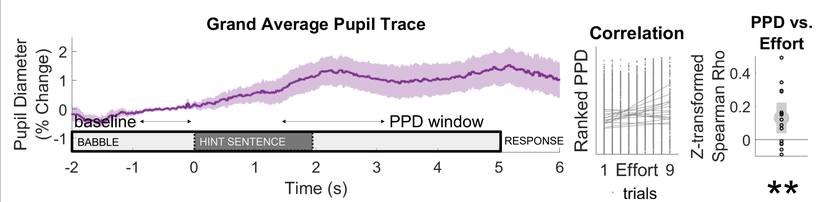
Analysis

- **Alpha:** Scalp data band-pass filtered from 8-12 Hz with absolute value of the Hilbert transform used as envelope. Power values at sources obtained by DICS beamforming [6] from 8-12 Hz. Trial by trial, mean alpha power during encoding determined for scalp data (1-1.5 sec window) and source data (1-2 sec window).
- **Effort:** Effort ratings organized trial by trial for all subjects
- **Correlations:** For every subject, trial by trial correlations done for alpha and effort ratings, effort ratings and Peak Pupil Diameter (PPD; 1.5-3.5 seconds), and alpha and PPD.

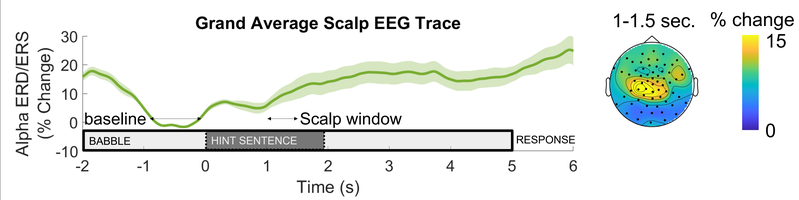
Results



Stimulus manipulations resulted in range of effort ratings used

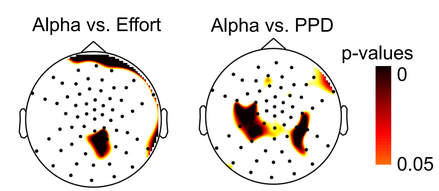


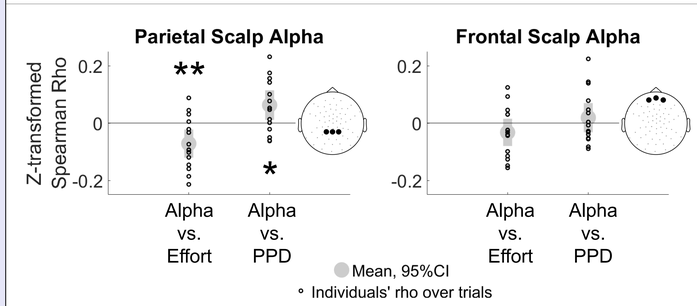
PPD and effort correlate



Alpha power during encoding has peak activity in centroparietal channels

Significance levels of alpha correlations with effort and PPD across the scalp show different ROIs. Only parietal and frontal channels tested based on our hypotheses

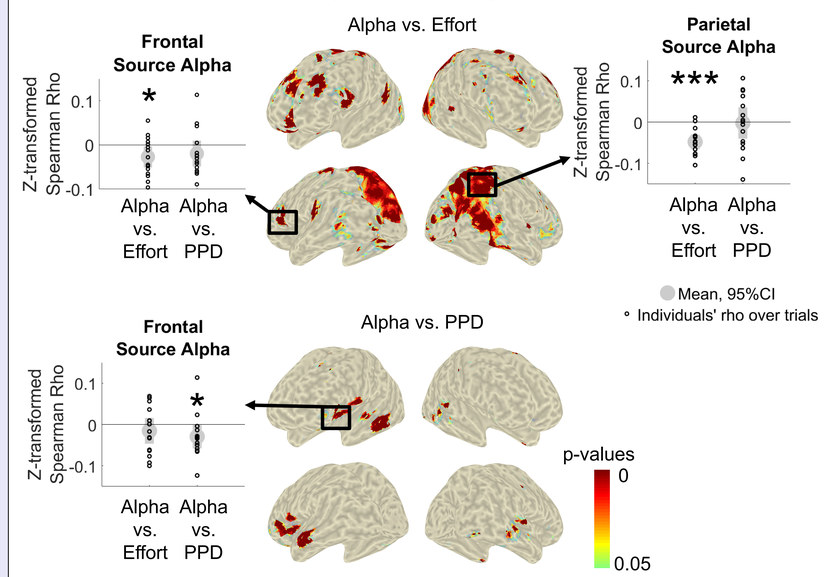




Previous findings [3] extended. Non-zero correlations found between parietal scalp alpha and PPD.

Results continued

Significance levels of alpha correlations with effort and PPD shown across the brain. ROIs include parietal and multiple frontal areas



Beamforming reveals relationships between alpha power and PPD in a frontal areas, specifically IFG pars opercularis (top) and IFG pars triangularis (bottom)

Discussion

- Relationships between alpha power and pupil diameter do exist, but depend on location
- Source rather than scalp data may help isolate signals from multiple alpha generators
- IFG also identified by previous study about alpha and effort [5]
- Open questions
  - How does SNR alone change neural responses?
  - What cognitive processes are reflected in alpha and pupil response?
  - Is PPD best metric to use?
  - How can pupillometry be clinically useful at the individual level?

References

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