Target-Related Alpha Attenuation in a Brain-Computer Interface (BCI) Rapid Serial Visual Presentation (RSVP) Calibration Task

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Background

- Brain-Computer Interfaces (BCIs) leverage neurophysiological input to assist users with tasks such as communication and movement.
- BciPy is an extant BCI platform for research and communication designed to capture attentional event-related potentials (ERPs) via a rapid serial visual presentation (RSVP) speller paradigm.
- Posterior alpha amplitude is a well-studied index of visual attention and processing that is measured using electroencephalography (EEG).
- Target-related alpha event-related desynchronization (ERD) is a likely candidate for addition to BciPy, alongside current classification procedures.

Research Questions

- Are target-related attenuations in alpha amplitude observable in the context of the BciPy RSVP Keyboard task?
- Do the size and significance of alpha ERDs change when the presentation rate of letter stimuli is varied?
- Between participants, do target-related alpha ERD effects co-vary with changes in target-related ERPs, particularly the N2 and P3?
- Can alpha ERD be used for target/non-target classification?
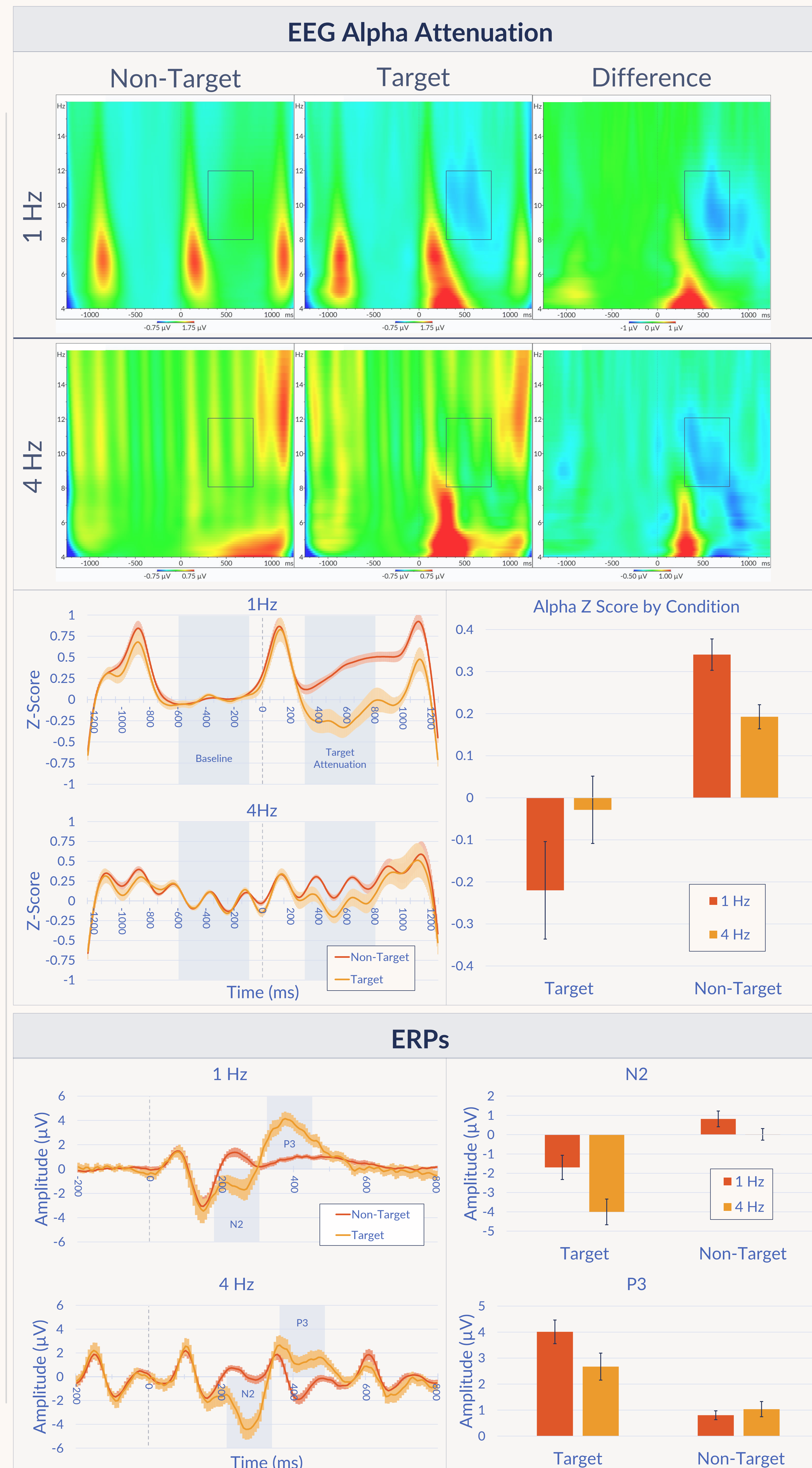
Participants & Task

- 12 generally healthy participants, age 28-46 years (Mean = 33.75; SD = 6.40)
    - 6 Female, 6 Male; 12 White (1 Hispanic/Latino)
- EEG collected using VR-300 dry electrode system (Wearable Sensing) during 2 instances of an RSVP Keyboard calibration: once at 1 Hz and again at 4 Hz (order randomized and balanced)
   - 100 sequences per calibration: prompt, followed by stream of 10 letters (1 target; 9 non-targets)
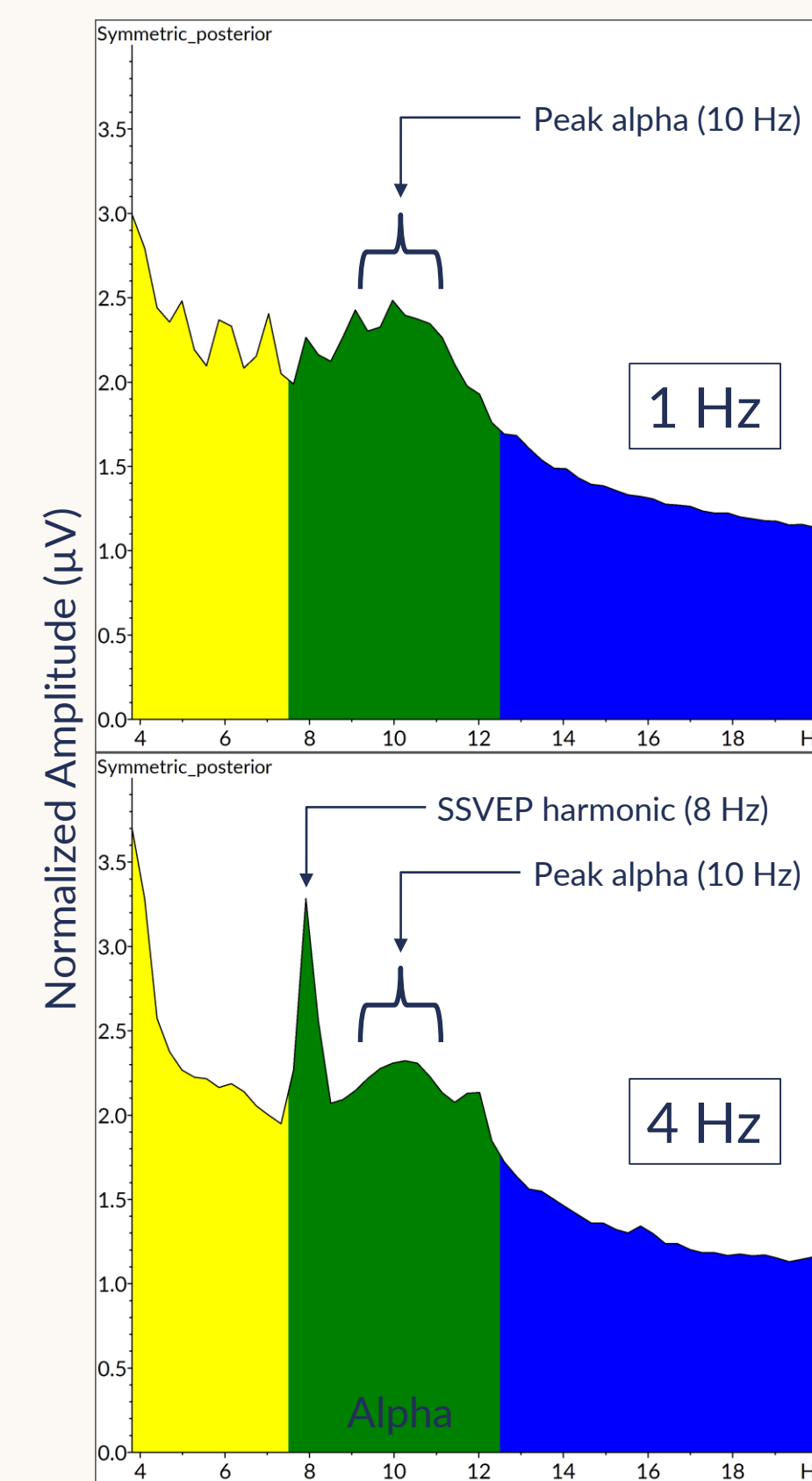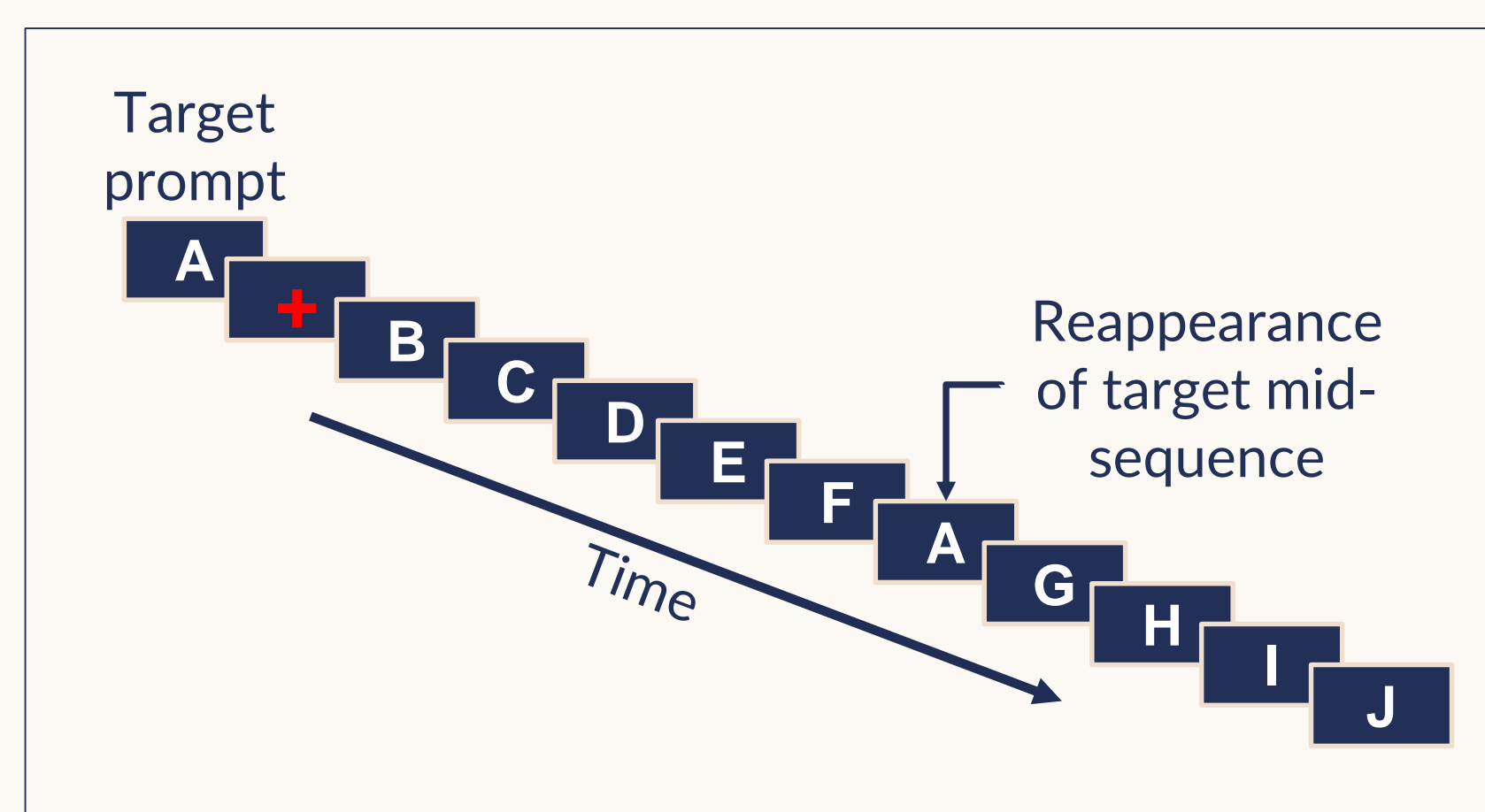
Rapid Serial Visual Presentation (RSVP)

Processing

- Sampling rate of 300 Hz, downsampled to 150 Hz
- Pooled parieto-occipital sites Pz, Oz, PO7, & PO8
- Filtered 1-45 Hz w/ 60 Hz notch
- Continuous Wavelet Transform (CWT)
    - 2.5 sec centered at letter stimuli onset
    - Extract real amplitude from Morlet complex at layer nearest individualized peak alpha
    - Change in alpha amplitude (Z score) 300 to 800 ms post-stimulus onset, relative to baseline (-600 to -100 ms)
- ERP Analysis
    - -200 to 800 ms, relative to stimulus onset
    - Mean amplitude +/- 4 samples (~53 ms) of peak N2 and P3 (~53 ms)

EEG Alpha Attenuation

ERPs
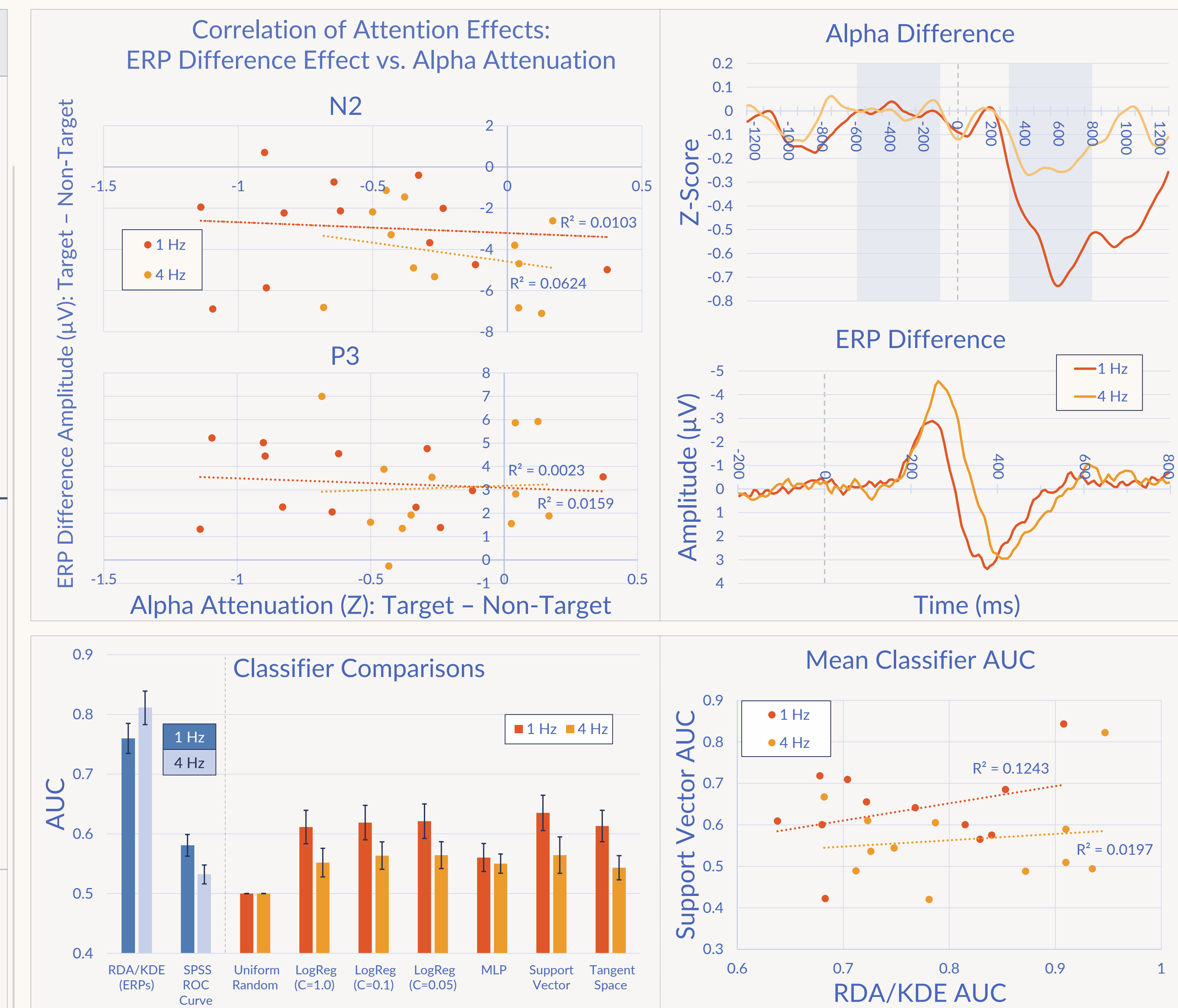
Results

- Alpha amplitude Z scores significantly lower across participants for target vs. non-target letter stimuli at both 1 Hz ($p = .001$) and 4 Hz presentation rates ($p = .022$)
- Within-participant alpha was higher ($p < .05$) for target vs non-target stimuli in 6/12 recordings at 1 Hz (+1 trending in the correct direction and another in the opposite, $p < .10$) and 3 at 4 Hz (+3 trending, $p < .10$)
- Target vs. non-target alpha difference was significantly smaller at 4 Hz compared to 1 Hz presentation condition ($p = .017$)
- As expected, N2 and P3 amplitudes were higher for target stimuli vs. non-targets (all p values < .01)
- N2 attentional amplitude effect (target minus non-target) greater at 1 Hz compared to 4 Hz ($p < .001$), but no such difference for P3 attention effect ($p > .6$)
- There were no significant correlations between alpha and ERP attention effects at 1 Hz or 4 Hz (p values > .4)
- No significant correlations between RDA/KDE AUC estimates and AUC estimates from any of the tested alpha classifiers (all p values > .11)
- Significant increase in RDA/KDE AUC from 1 Hz to 4 Hz ($p = .001$) and significant decreases in AUC for all alpha classifiers from 1 Hz to 4 Hz (all p values < .05), with the exception of MLP ($p = .54$)

Conclusions

- Alpha ERD effect is measurable for target vs. non-target letters in RSVP and is sensitive to stimuli presentation rate
- N2 & P3 ERP amplitudes are unrelated to attentional alpha ERD effects
- Target/Non-Target classification of alpha changes is poor in isolation when compared to classification of ERP time-series data, possibly due in part to individual differences in the time course of target-related alpha attenuation
- Future investigations should pursue optimization and individualization of alpha ERD classification and also integration of alpha with ERP signals