



Finding Meaning in Music: N400 Indices of the Semantics of Musical Intervals

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Background

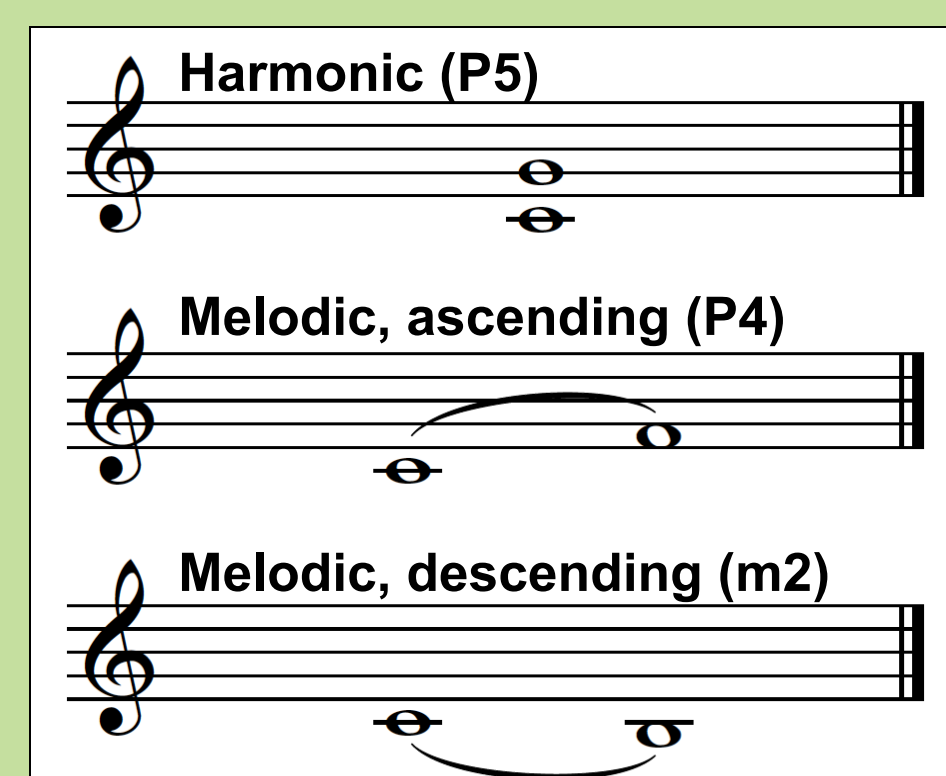
- ❖ The N400 event-related brain potential (ERP) component is a negative-going waveform that appears to index the degree of semantic fit for a word, given a preceding context.¹⁻⁴
 - ❖ Larger N400 amplitudes observed in response to incongruent final words in a sentence, compared to congruent words.¹
 - ✓ e.g. "I like cream and sugar in my *socks*" (vs. congruent word "*coffee*")
 - ❖ Larger N400 amplitudes observed in priming studies when target words are preceded with an unrelated prime, vs. a related prime.³
 - ✓ e.g. "*apple – nurse*" (unrelated) vs. "*doctor – nurse*" (related)
- ❖ Prior ERP research suggests that music is capable of establishing a semantic context.
 - ❖ Short (1 to 10 second) musical clips elicit N400 effects in the processing of congruent and incongruent word targets, similar to the effects observed in language.⁵⁻⁷
 - ❖ However, little previous research examines the extent to which smaller units of music can establish a semantic context.

Goal & Hypothesis

- ❖ The present study examines whether an isolated element of music (the musical interval) can provide sufficient semantic context to influence the processing of a linguistic target.
 - ❖ In a relatedness judgment task (RJT), words preceded by an experimentally-determined unrelated musical prime will elicit larger N400 amplitudes relative to words preceded by related musical primes.

Stimulus Set Creation: Methods and Results

- ❖ 144 prime-target pairs were created for the ERP experiment and subjected to 2 behavioral pilot studies.



Auditory Primes:
12 chromatic intervals presented in 3 presentation modes.



Word Targets:
English words presented visually, white text on black background.

Pilot 1

- ❖ 33 participants (ages 18-64, 23 female) rated the relatedness of 108 prime-target pairs created by two trained musicians.
- ❖ For each distinct auditory prime, two targets with the highest average relatedness score were retained for further testing (total of 72 prime-target pairs, deemed "related").

Pilot 2

- ❖ Related word targets retained from Pilot 1 were re-matched with auditory primes to create a set of unrelated prime-target pairs using the same stimuli.
- ❖ 120 undergraduate participants rated the relatedness of all prime-target pairs.
- ❖ A significant difference was found between the mean relatedness scores for related and unrelated stimulus pairs (two-tailed paired samples t-test, $p < .001$, $d = 1.13$), and related pairs received higher relatedness ratings on average than unrelated pairs ($M_{related} = 4.61$, $M_{unrelated} = 3.62$; 8-point Likert scale).
- ❖ These findings supported and recommended the use of this stimulus set for the ERP experiment.

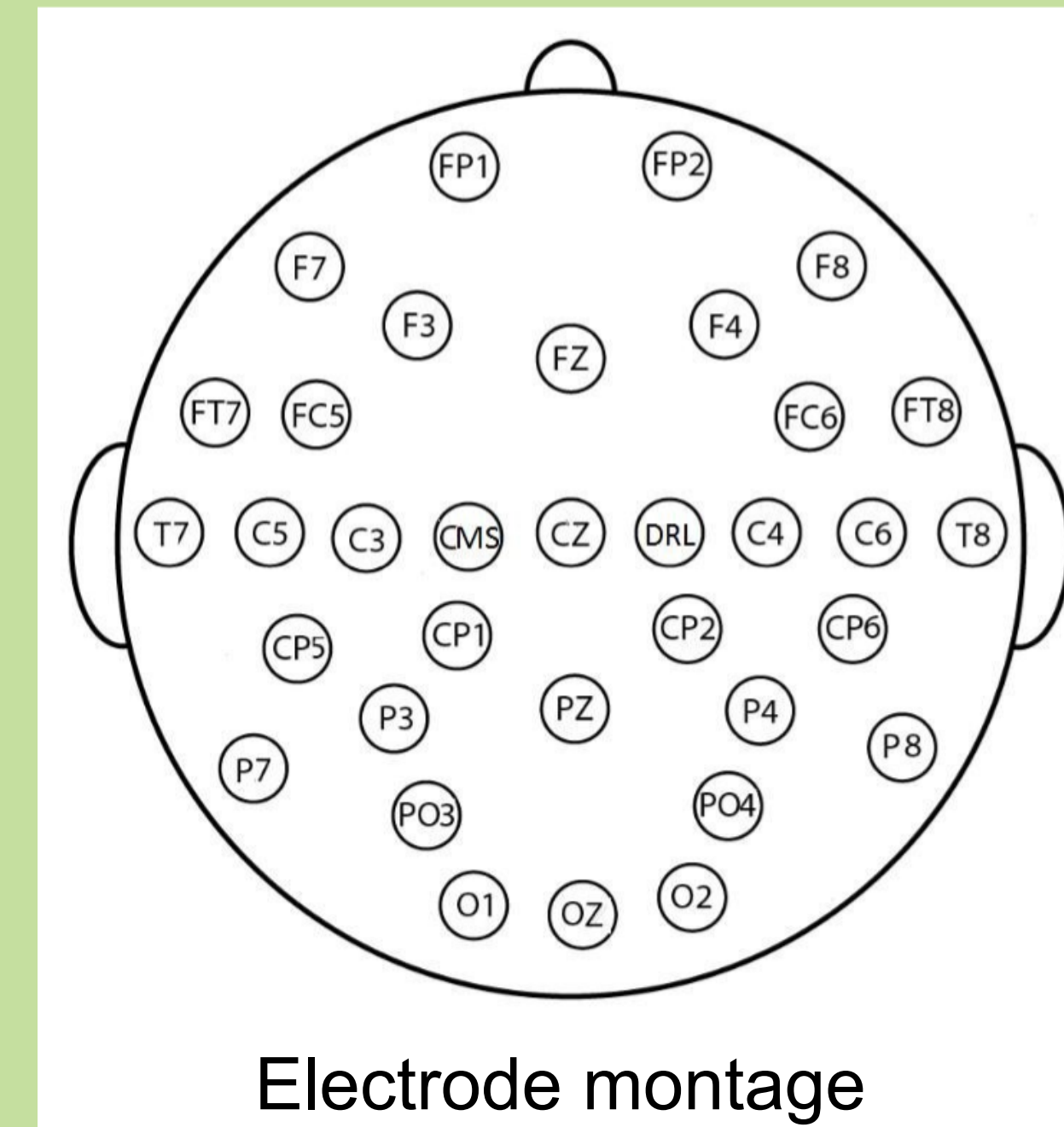
ERP Experiment: Methods

Participants

- ❖ 21 undergraduate students (ages 18-21, 9 female) participated in the ERP experiment.

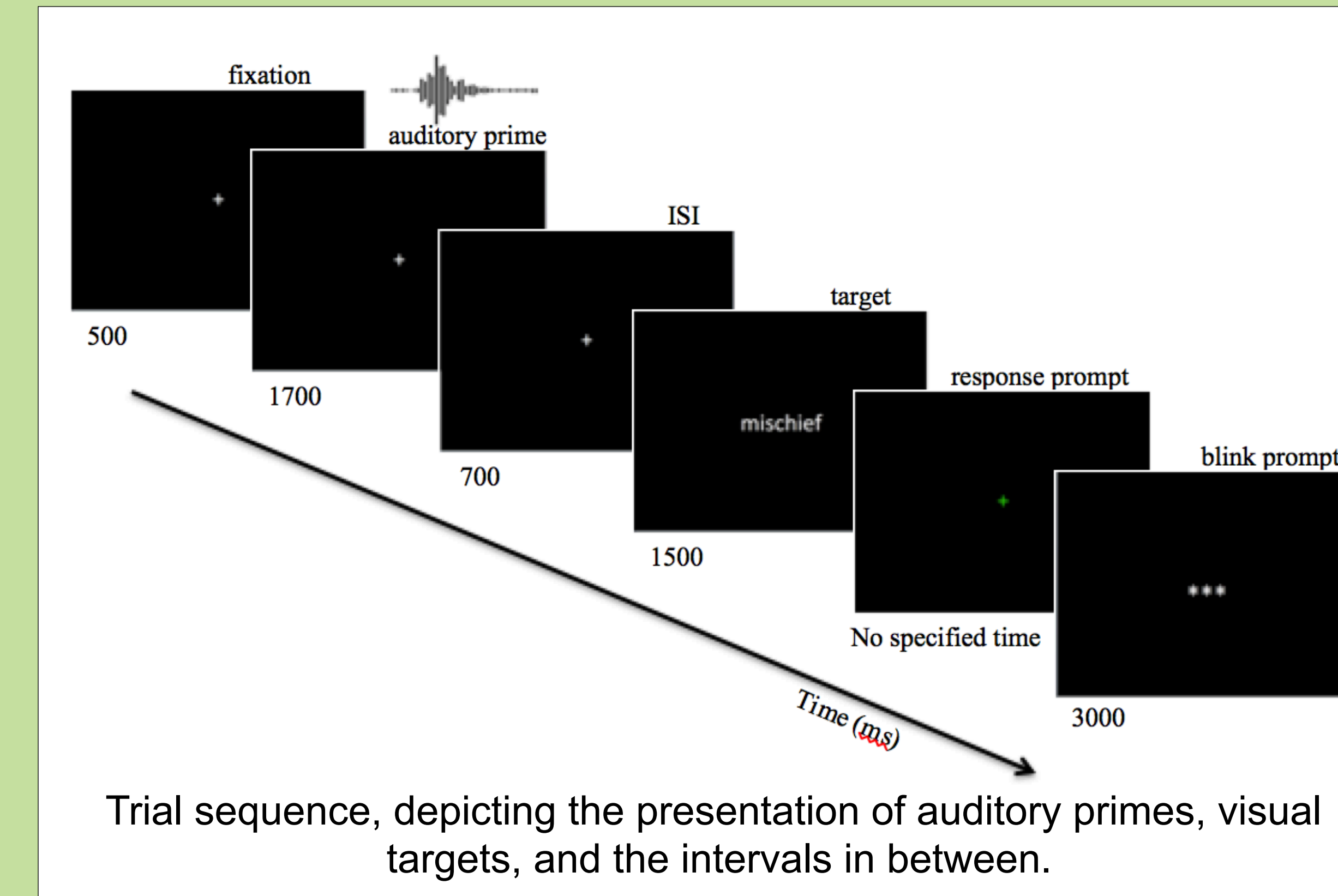
Equipment & ERP Recording

- ❖ Auditory stimuli presented on a pair of free-standing speakers, 65 cm from each ear. Visual stimuli presented on a computer monitor 120 cm in front of the participant.
- ❖ EEG recorded from 32 electrodes (International 10/20 system) using BioSemi Active Two system; re-referenced to the mean of left and right mastoids, down-sampled to 256 Hz from 1024 Hz, bandpass 0.1-40 Hz.
- ❖ ERPs time-locked to the onset of 1500 ms target word stimuli.
- ❖ EEG divided into epochs from 100 ms before stimulus onset to 1000 ms post stimulus onset.



Procedure

- ❖ Participants determined the relatedness of visual target words to preceding auditory primes (two-alternative forced choice: "related," "unrelated").
 - ❖ Prior research suggests that this relatedness judgment task (RJT) produces more robust N400 effects than other tasks (e.g. memory tasks, lexical-decision tasks).^{5,7}

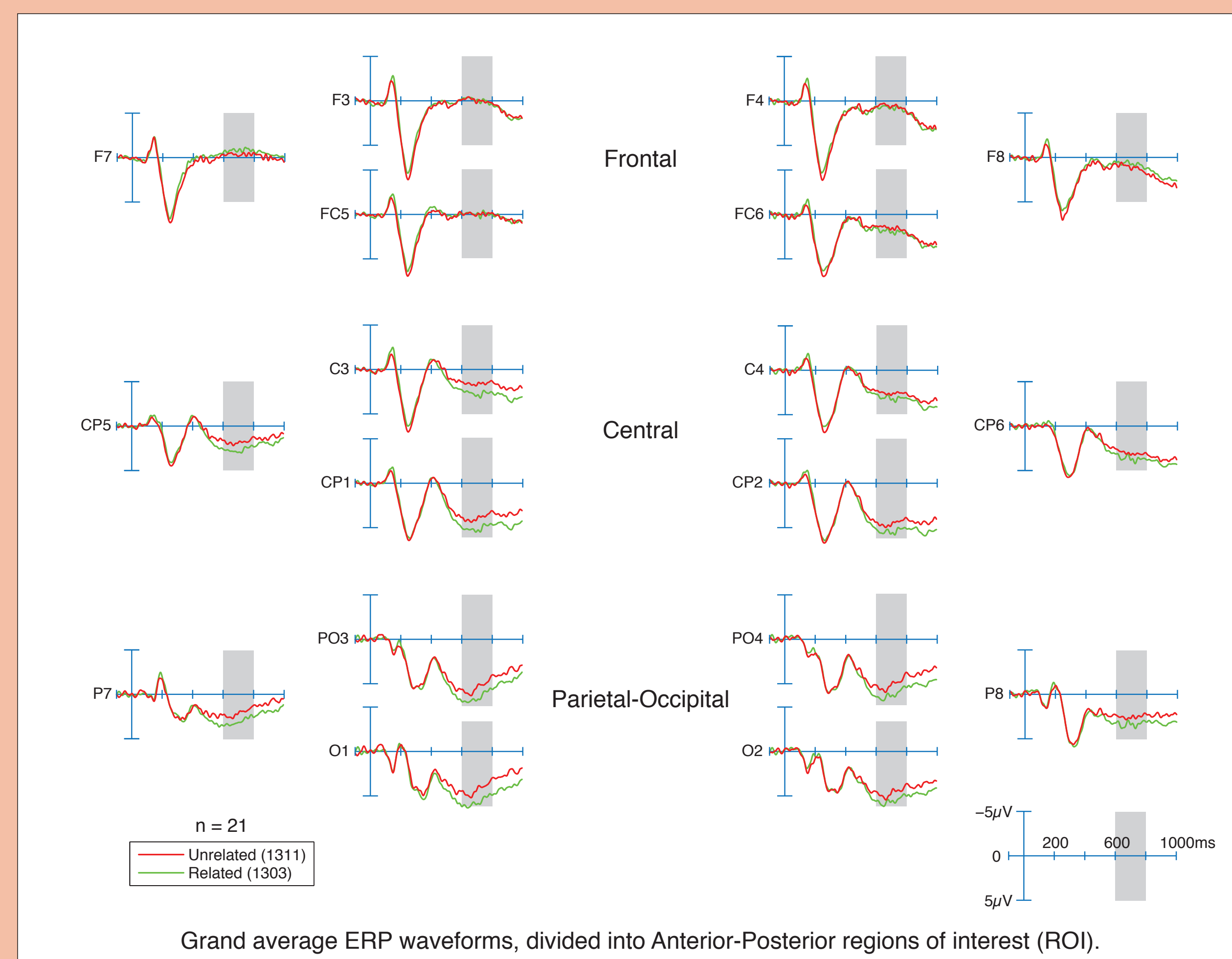


- ❖ Stimuli were presented in 6 blocks of 24 trials each. Both block and trial order were randomized for each participant.

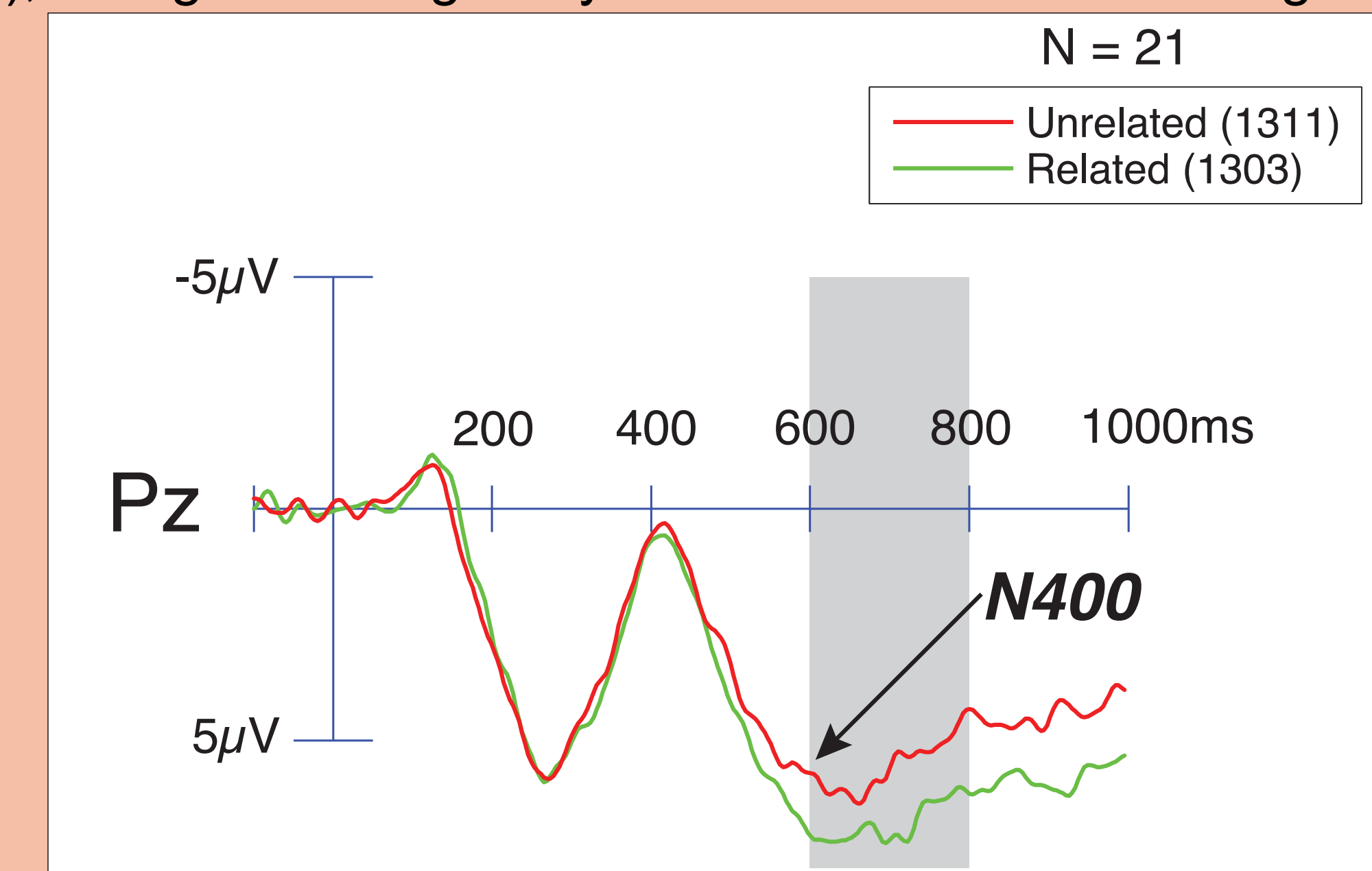
ERP Experiment: Analysis & Results

Analysis

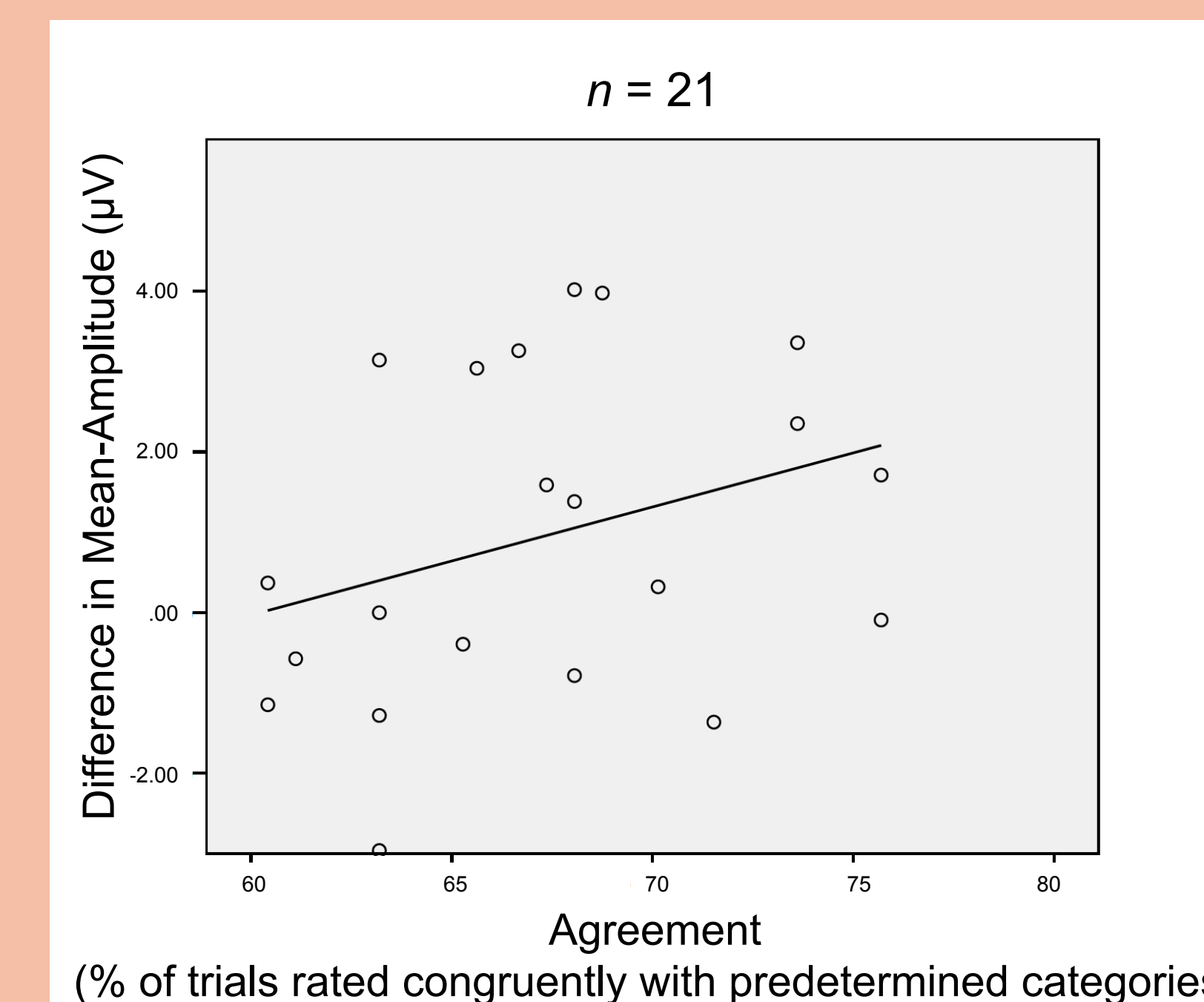
- ❖ Mean amplitudes measured from 600-800 ms post-stimulus onset, based on visual inspection of individual and grand averaged waveforms.
- ❖ Measures of mean amplitude from 600-800 ms subjected to a 2x2x3 repeated-measures ANOVA with 3 factors:
 - ❖ Relatedness of targets to primes (related, unrelated)
 - ❖ Hemisphere (left, right)
 - ❖ Anterior-Posterior (frontal, central, parietal-occipital)
- ❖ Results from the ANOVA indicated an effect of relatedness largest over central and parietal-occipital electrode sites (Relatedness x Anterior-Posterior, $F(2, 40) = 6.61$, $p < .05$, $\eta_p^2 = .248$).



- ❖ Follow-up paired t-tests focused on central and parietal-occipital ROIs and indicated a significant difference between mean amplitude measures in the related and unrelated conditions (two-tailed, $t(20) = -2.147$, $p < .05$, $d = 0.47$), with greater negativity to unrelated vs. related targets.



- ❖ Correlation between mean-amplitude difference and participants' agreement with related-unrelated categorization (determined a priori) revealed a medium effect size ($r = .318$), but was not statistically significant ($p = .16$).



Discussion

- ❖ Musical intervals demonstrate the ability to prime a semantic context that affects the processing of subsequently presented words.
- ❖ Effects of semantic priming were observed from 600-800 ms post stimulus-onset over central and parietal-occipital electrode sites, with increased negativity for unrelated primes compared to related primes.
 - ❖ Delayed latency of this effect is consistent with previous research on semantic processing involving less-familiar stimuli (e.g. non-native language⁹ and texted English¹⁰).
 - ❖ Central-parietal distribution is reported in studies of the N400 effect in both language and music.^{1,5,7,11}
- ❖ Although not significant in this study, N400 amplitude may be sensitive to the degree of agreement between a participant's relatedness ratings and a priori-determined ratings.
- ❖ Based on the findings from and limitations of this study, future research could examine the following:
 - ❖ Cultural specificity of this effect. *Investigating across cultures would determine if musical intervals gain semantic weight through cultural experience or inherent acoustic properties.*
 - ❖ Implicitness of this effect. *A non-RJT task could be used to determine if semantic processing on this level is implicit or solely explicit.*
 - ❖ Specificity of this effect. *Musical elements such as rhythm, tempo, or amplitude might also result in semantic processing of music.*

References

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