Discourse-level Semantic Unification: ERPs and Oscillatory Neuronal Dynamics

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Background

1) Discourse-level information can have an effect on unification during language comprehension [a].
2) Beta oscillations seem to be related to syntactic unification [b].
3) Gamma oscillations seem to be related to semantic unification [c].
4) Discourse-level factors can sometimes have even stronger effects on ERP responses than local sentence-level factors [d].

We manipulated the discourse-level factor semantic coherence in order to investigate its influence on gamma oscillations related to sentence-level semantic unification. We were also interested in whether beta oscillations related to syntactic unification were influenced by whether or not sentences were embedded within a wider discourse context.

Main Research Question

Does semantic coherence in short discourses have an effect on unification and is this reflected in ERP or oscillatory brain responses?

Methods

Partcipants read short stories visually presented one word at a time (RSVP) in the center of a computer screen while their EEG was recorded (60 scalp electrodes).

Stimuli

1) Dutch short stories, 4 sentences per story, 10 words per sentence.
2) Coherent (COH) condition - all sentences fit together to make a coherent story.
3) Incoherent (INCOH) condition - sentences comprising the 'stories' were unrelated.
4) 40 items per condition for the main comparison and 20 filler items where coherence breaks down at sentences 3 (10 items) or 4 (10 items).

COH
Charles left his home country Senegal to work in Europe
With a dangerously small boat he was smuggled to Tenerife.
There he had to work hard for very little money.
His family desparately needed the money that he was sending.

INCOH
Charles left his home country Senegal to work in Europe
One evening they left a hot pie in the kitchen.
Coincidentally a cop came around the corner that arrested them.
But after just a year it was ready for the dump.

Stimuli were rated by a separate group of participants on a 7 point Likert scale to indicate how well each sentence fit with the previous sentence (1 = not at all and 7 = very well). All sentences in the COH condition were rated very highly. Sentences 2, 3, and 4 in the INCOH condition had very low ratings. Thus coherence in the INCOH condition was absent as desired.

Analysis details

1) Segmented data into individual words and averaged within each sentence and condition.
2) Standard ERP analysis with two time-windows of interest for the N1 (100-250 ms) and N400 (350-550 ms) components.
3) Multitaper-based time-frequency (TF) analysis of power changes [e].
4) Non-parametric cluster-based random permutation statistics [f] were used for significance testing with ERPs and TF data.

Hypotheses

1) Increase in beta power over the course of each sentence and return to baseline during inter-sentence interval periods independent of condition.
2) Increase in gamma power over the course of entire stories for the coherent condition but decreased gamma power starting around the second sentence for the incoherent condition.
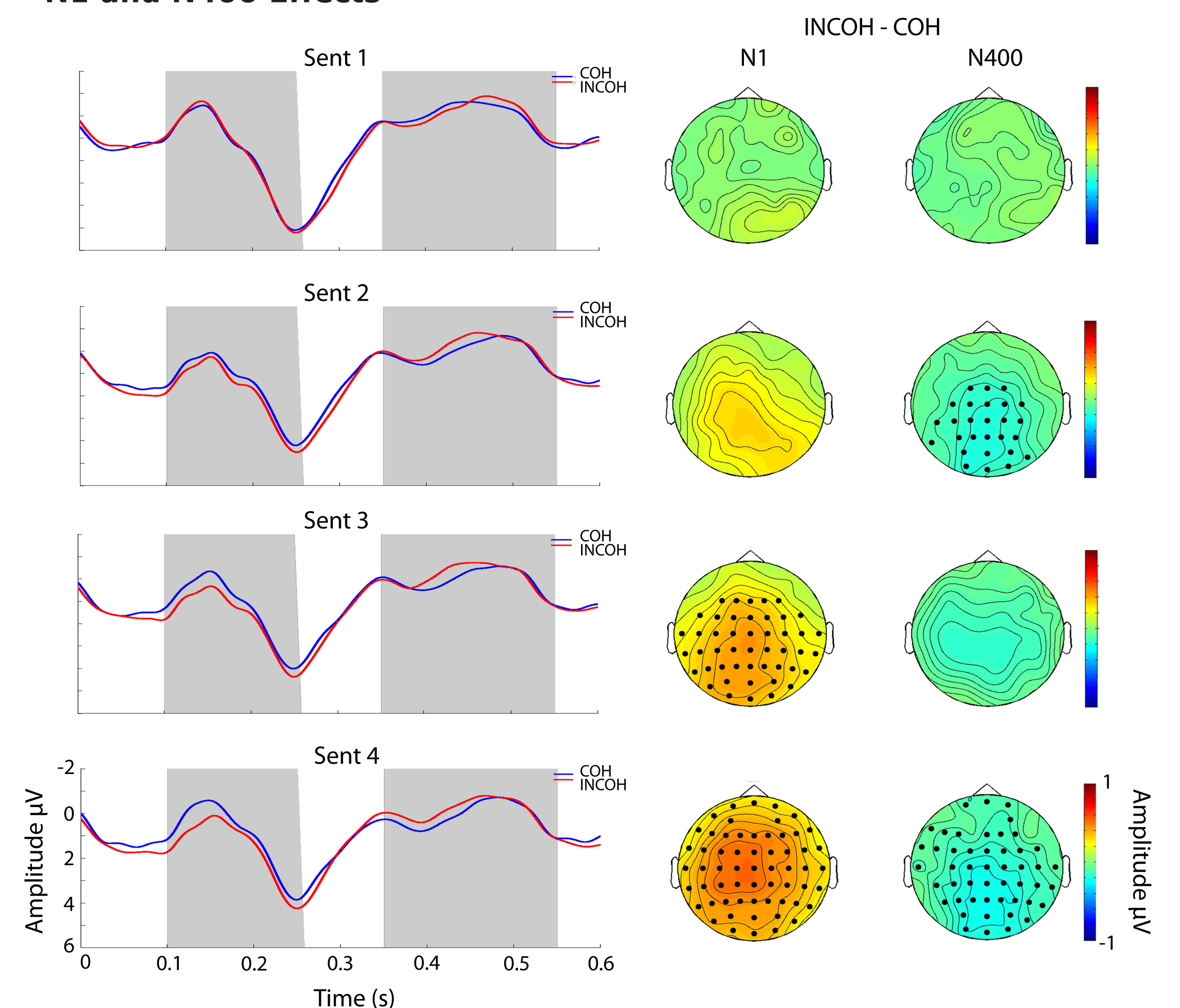
Results

N1 and N400 Effects

Figure 1: ERPs show a more negative N1 for the COH (blue waveform) than the INCOH (red waveform) condition, while the N400 is more negative for the INCOH condition than the COH condition at sentences 2-4. The N1 difference topography shows that the effect is centro-parietally distributed and only becomes significant at sentences 3 and 4 (significant electrodes marked by black dots). The N400 effect shows a centro-parietal distribution and is significant for sentences 2 and 4. Time windows of interest are marked in grey.
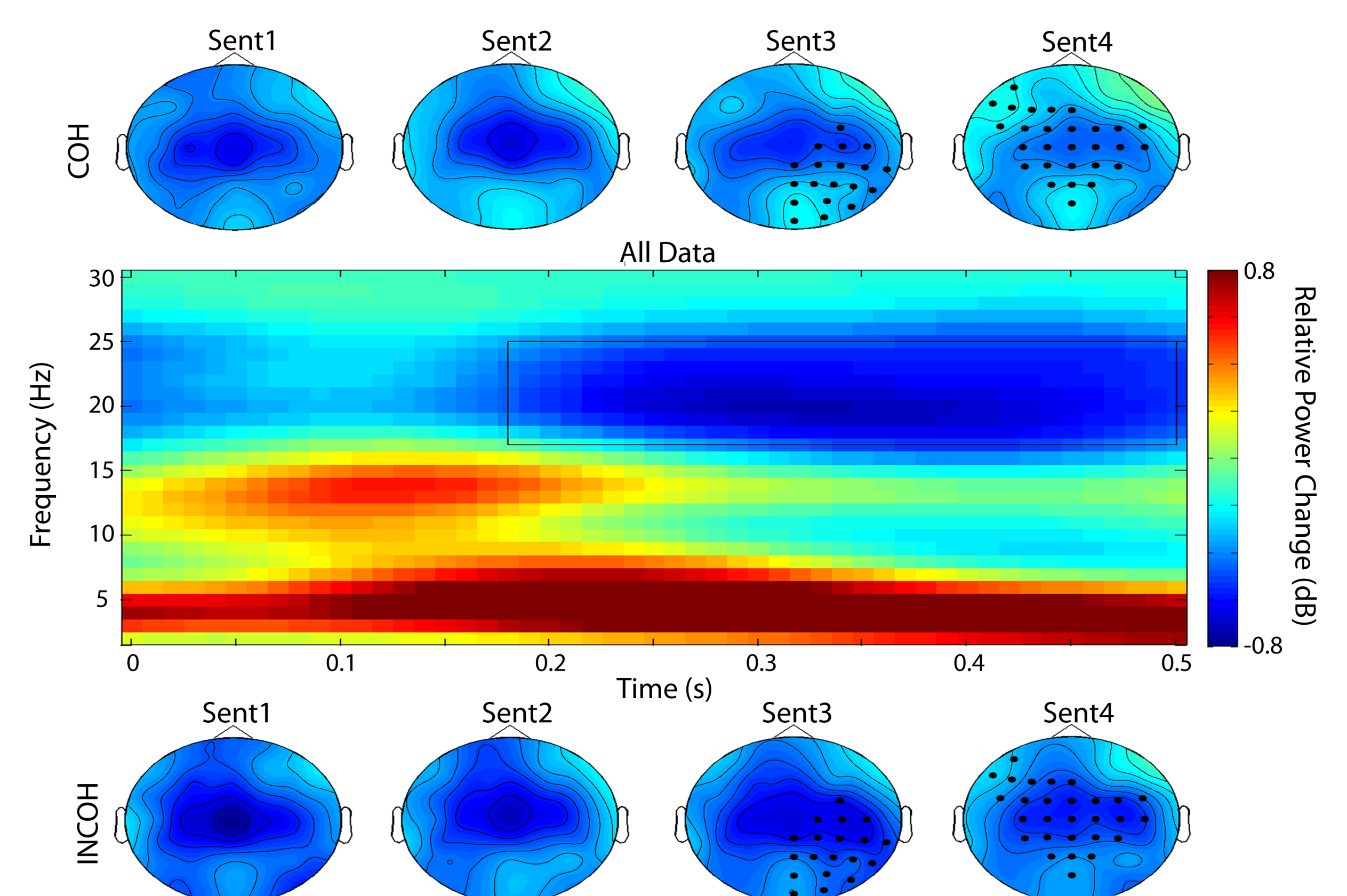
Beta TF Effects

Figure 2: TF results show a beta desynchronization between 17 and 25 Hz from 0.18 to 0.5 s after word onset (black box). It starts out strongest at central electrodes and becomes more widespread over the course of the stories. The beta decrease is larger in the INCOH condition than the COH condition for sentences 3 and 4. Increases in power in the theta and alpha/beta range are also visible, but inter-trial coherence (ITC) values indicate that these are likely evoked responses.

Discussion

1) The N1 effect may indicate that participants allocate more attention to the stimuli in the COH condition, perhaps processing the INCOH stimuli less attentively.
2) An N400 effect likely reflects the fact that semantic unification may be disrupted (at least to some extent) in the INCOH condition compared to the COH condition.
3) Lower beta power (greater desynchronization) for the INCOH condition may indicate syntactic unification difficulties compared to the COH condition.

References

a. P. Hagoort, J. van Berkum, Phil Trans R Soc B, 362 (2007).
b. M. Bastiaansen, L. Magyari, P. Hagoort, JOCN, 22(7) (2010).
c. L. Hald, M. Bastiaansen, P. Hagoort, B&L, 96 (2006).
d. M. Nieuwland, J. van Berkum, JOCN, 18(7) (2006).
e. P. Mitra, B. Pesaran, Biophys J, 76(691) (1999).
f. E. Maris, R. Oostenveld, J Neurosci Methods, 164(177) (2007).