Alpha and Theta Power are Sensitive to Semantic but not Syntactic Retrieval Interference

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Background

1) In the cue-based framework, retrieval interference due to both semantic and syntactic feature overlap has been demonstrated behaviorally (Van Dyke, 2007).

2) Memory retrieval has been related to neural oscillations in the theta (4-8 Hz), alpha (8-12 Hz), and gamma (30Hz and above) bands (Spitzer et al., 2009).

3) Syntactic and semantic integration are linked to beta (13-30 Hz) and gamma oscillations (Lewis et al., 2015).

4) Increased alpha power is associated with active suppression of competing alternatives in short-term memory (Bonnefond et al., 2012).

We manipulated the level of semantic and syntactic retrieval interference between a retrieval cue and its antecedent in a sentence in order to investigate the influence of these two factors on theta, alpha, beta, and gamma oscillations. Of particular interest is to demonstrate a relationship between oscillatory power in one (or multiple) of these frequency ranges and comprehension accuracy, as an index of whether or not interference was detected and resolved.

Main Research Questions

> **What are the oscillatory neural signatures of semantic and syntactic retrieval interference, are they similar/different depending on interference type, and how are they related to comprehension?**

Methods

Partcipants (n=28) read relative clause sentences visually presented one word at a time in the center of a computer screen while their EEG was recorded (64 scalp electrodes). Every sentence was followed by a comprehension question to assess comprehension accuracy.
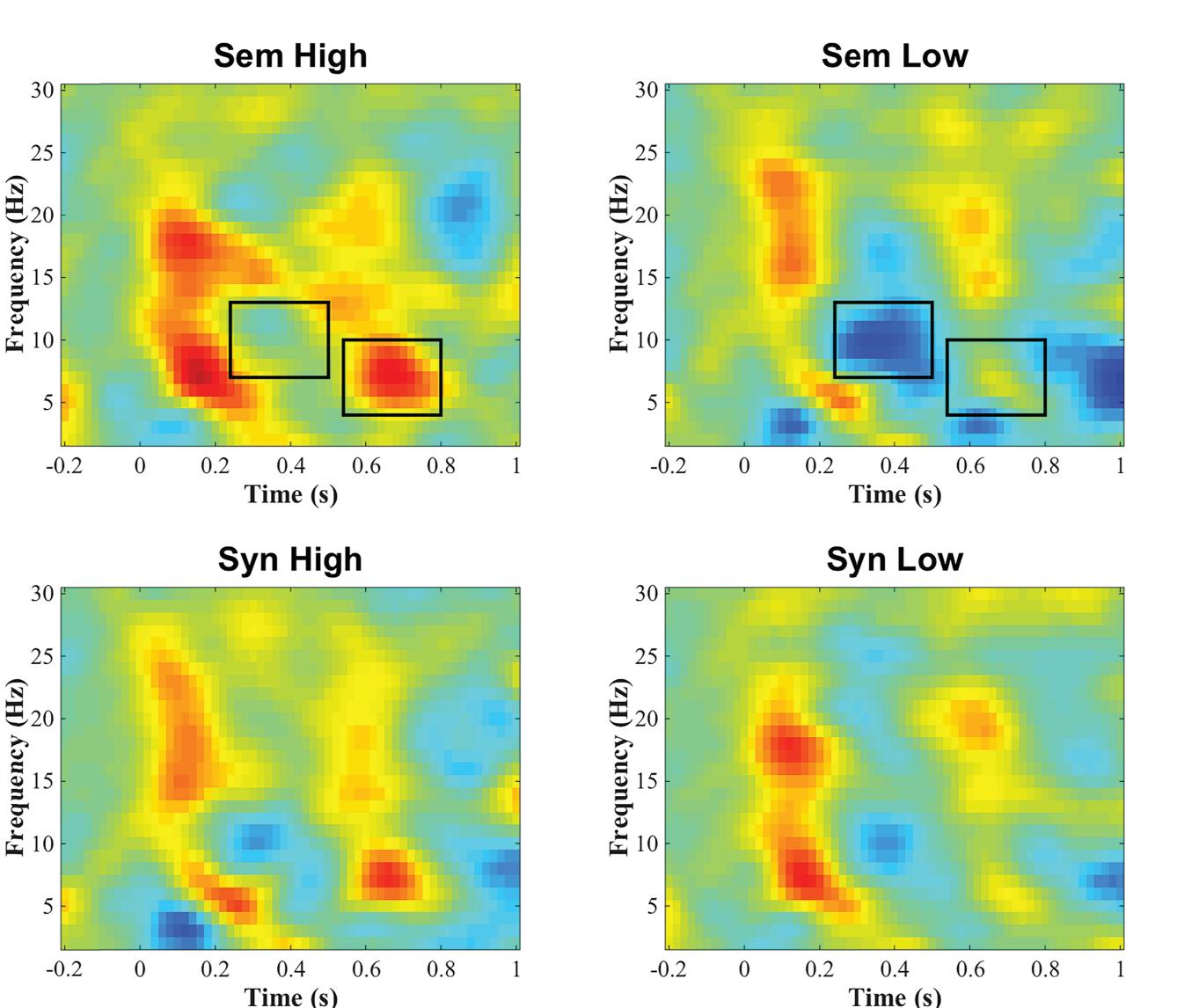
Stimuli

1) English sentences varying semantic and syntactic retrieval interference.

2) 40 items per condition (160 total) with 80 filler items.

3) SemLowSynLow sentences: intervening referent inanimate - not potential grammatical subject.

   The young priest said that *the thief* who had stolen from the strict church for some time **lived** near the sanctuary.

4) SemHighSynLow sentences: intervening referent animate - not potential grammatical subject.

   The young priest said that *the thief* who had stolen from the strict nun for some time **lived** near the sanctuary.

5) SemLowSynHigh sentences: intervening referent inanimate - potential grammatical subject.

   The young priest said that *the thief* who knew that the church was strict for some time **lived** near the sanctuary.

6) SemHighSynHigh sentences: intervening referent animate - potential grammatical subject.

   The young priest said that *the thief* who knew that the nun was strict for some time **lived** near the sanctuary.

Hypotheses

1) The level of retrieval interference (high vs low) is expected to modulate oscillatory power in one or all of the theta, alpha, beta, and gamma frequency bands.

2) The frequency range modulated by interference may be dependent on interference type.

3) Alpha power is expected to be higher for high compared to low interference conditions, indexing active suppression of interfering information in memory.
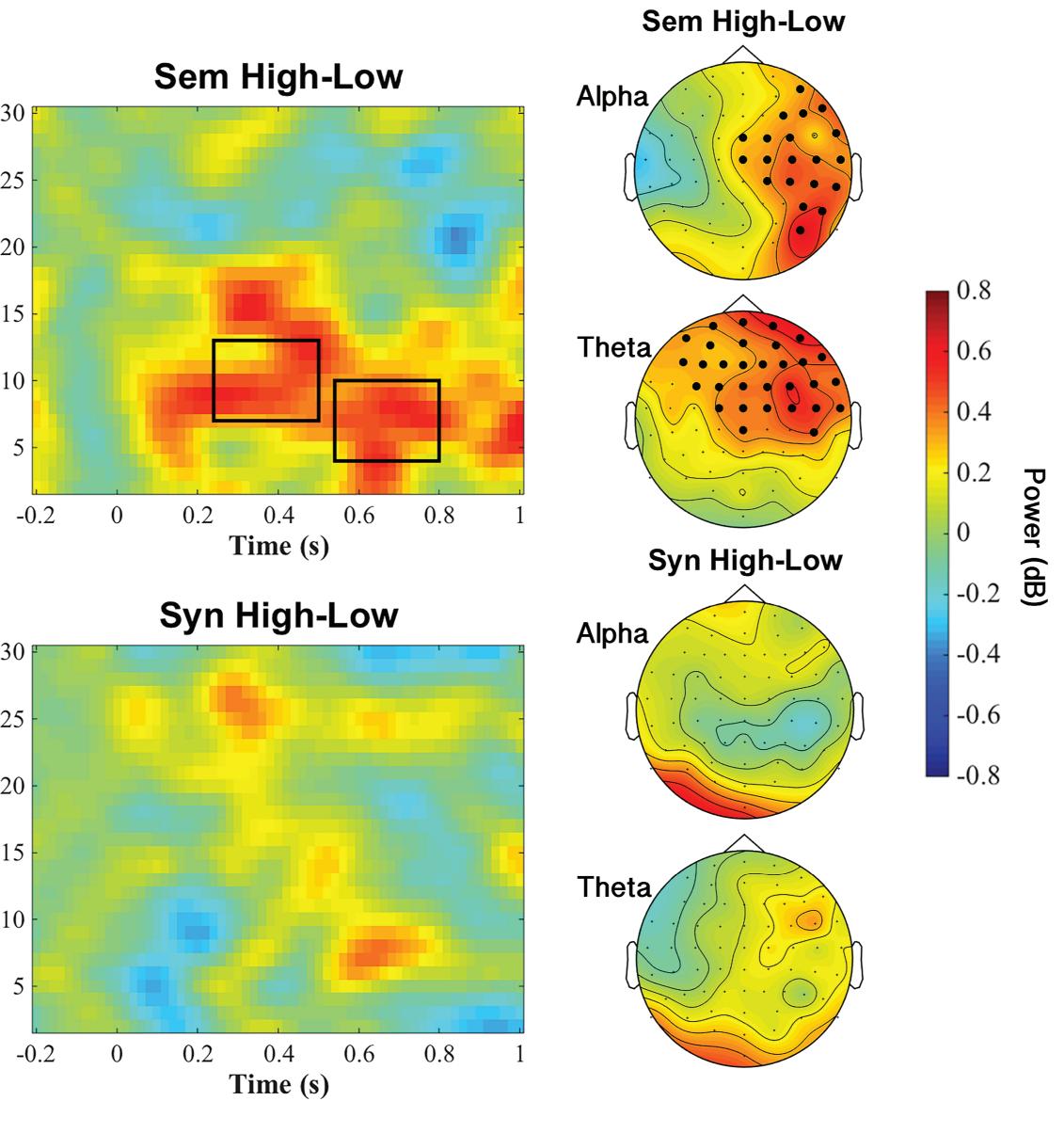
Time-frequency Results

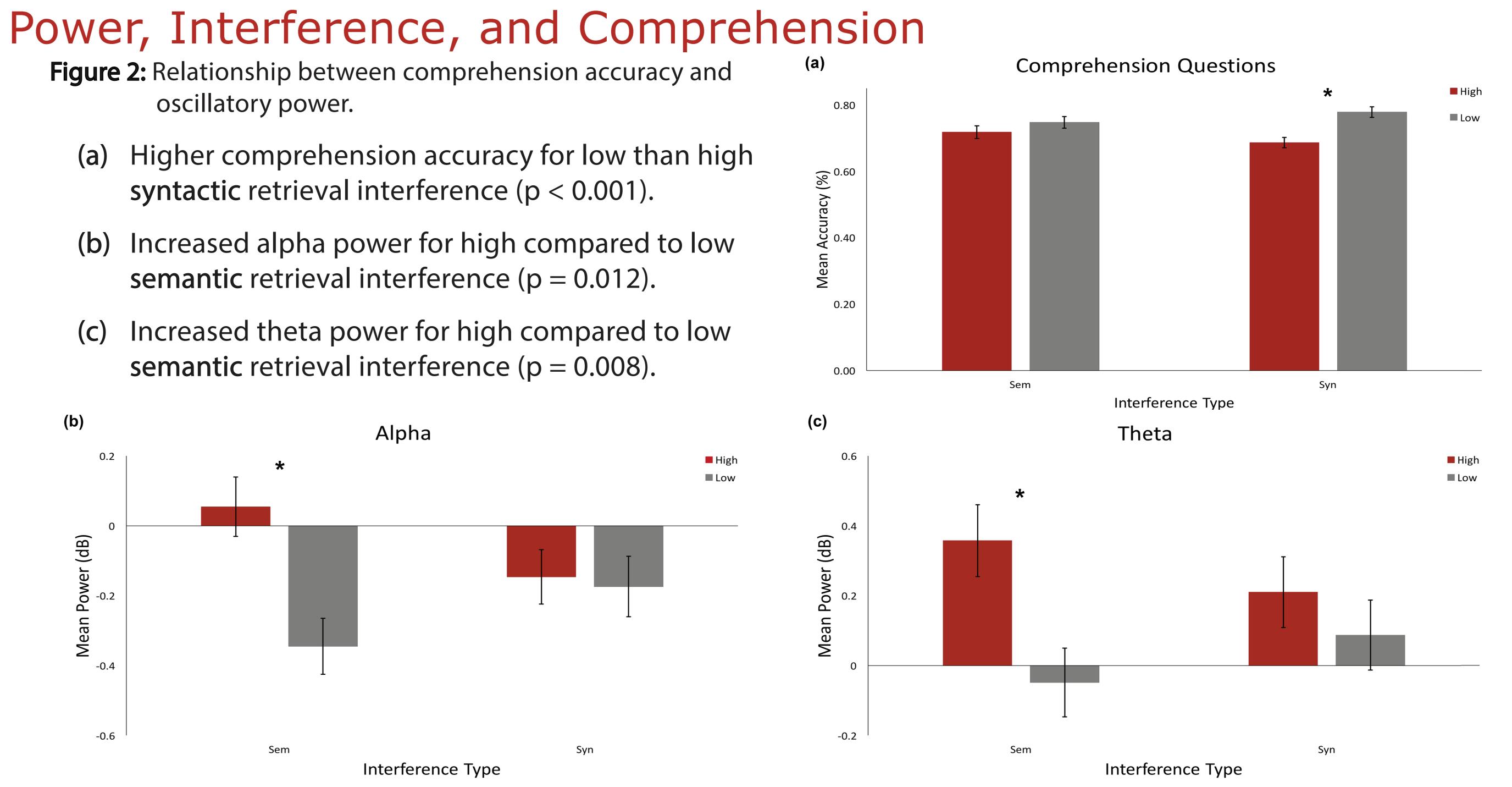**Figure 1:** Time-frequency results for the low frequency range (2-30 Hz).

a) Early (0.25-0.5 s) right posterior alpha (7-13 Hz) power difference for **semantic** interference.

b) Later (0.55-0.8 s) frontal theta (4-10 Hz) power difference for **semantic** interference.

c) No statistically significant power differences for **syntactic** interference.

d) No statistically significant power differences in high (28-100 Hz) frequency range.

Analysis Details

1) Data epochs around target words (-1 to 2 s) per condition; standard preprocessing & artifact rejection/correction.

2) Multitaper time-frequency analysis of power (Mitra & Pesaran, 1999).

4) High (28-100 Hz) vs low (2-30 Hz) frequencies analyzed separately to optimally deal with the time-frequency precision tradeoff.

5) Data grouped in the following way: Sem Low = (SemLowSynHigh+SemLowSynLow)/2;
   Sem High = (SemHighSynHigh+SemHighSynLow)/2; Syn Low = (SemHighSynLow+SemLowSynLow)/2;
   Syn High = (SemHighSynHigh+SemLowSynHigh)/2.

5) Non-parametric cluster-based random permutation statistics (Maris et al., 2007) used for significance testing in the high and low frequency ranges separately.

6) Repeated measures ANOVA for statistical analysis of accuracy data.

Power, Interference, and Comprehension

Figure 2: Relationship between comprehension accuracy and oscillatory power.

(a) Higher comprehension accuracy for low than high **syntactic** retrieval interference (p < 0.001).

(b) Increased alpha power for high compared to low **semantic** retrieval interference (p = 0.012).

(c) Increased theta power for high compared to low **semantic** retrieval interference (p = 0.008).

Discussion

1) Increased right posterior alpha power at the target word during sentence reading reflects active inhibition of competing referents for high compared to low **semantic** retrieval interference.

2) Increased frontal theta power at the target word when **semantic** retrieval interference is high reflects the increased memory demands (Jensen et al., 2002) related to selecting the appropriate referent and recovering the correct sentence meaning.

3) The presence of these two neural indices co-occurs with comparable good comprehension accuracy between high and low **semantic** retrieval interference conditions, implicating these signatures in the adequate resolution of **semantic** retrieval interference.

4) Neither of these neural signatures are observed when comparing high and low **syntactic** retrieval interference, suggesting that participants do not engage in the requisite processing to overcome **syntactic** retrieval interference.

5) This translates to a comprehension accuracy decrement in the high compared to low **syntactic** retrieval interference condition, suggesting that this type of retrieval interference is not adequately resolved.

6) Next steps are to test whether single-trial alpha and/or theta power are predictive of comprehension accuracy, and to localize the cortical sources of this activity.

References

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