Theta-gamma phase-amplitude coupling as a neural signal of events in language

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Theta-gamma PAC may be a marker for events with minimal object state-change

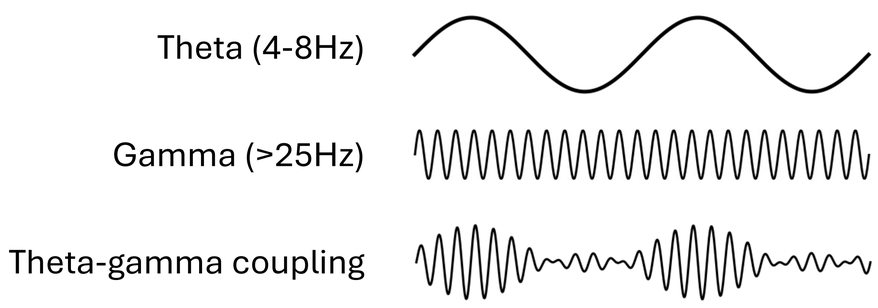
1. Introduction

There is evidence that multiple object-states are simultaneously represented and maintained in the brain when comprehending state-change events, e.g. "The girl will chop the bagel"[1,2]. Yet we can differentiate **what** these states are and **when** they existed.

Question: What are the neural dynamics that underlie these simultaneous representations?

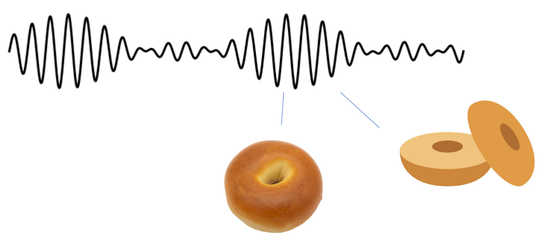
Hypothesis: Brain maintains multiple representations using a theta-gamma neural code

What is theta-gamma coupling? Theta-gamma coupling happens when the **amplitude** of a *gamma* (high-freq.) oscillation is modulated by the **phase** of a *theta* (low-freq.) oscillation.



What behavior is it linked to? Maintaining a sequence of items in working memory has been shown to recruit frontotemporal theta-gamma coupling[3,4,5,6].

What does the theta-gamma signal code for? Individual gamma cycles nested within a theta-wave have been hypothesized to encode **individual items** in working memory[7]. In the context of object state-change events, they may represent **individual object-states.**



2. Methods

Task

N=69 across two EEG studies (secondary analysis of existing data)
Word-by-word presentation on screen, occasional comprehension questions
Manipulation of interest: degree-of-change
~30 trials per condition per subject

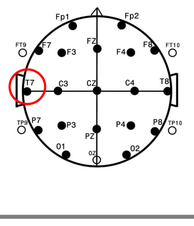
Deg. of change	First sentence	Second sentence
Minimal	The girl will choose the bagel.	And then she will smell the bagel.
Substantial	The girl will chop the bagel.	

Specs

256-channel EGI HydroCel Geodesic Sensor Net
Original sampling rate 1000Hz, downsampled to 250Hz
Bandpass filter: 1-80Hz

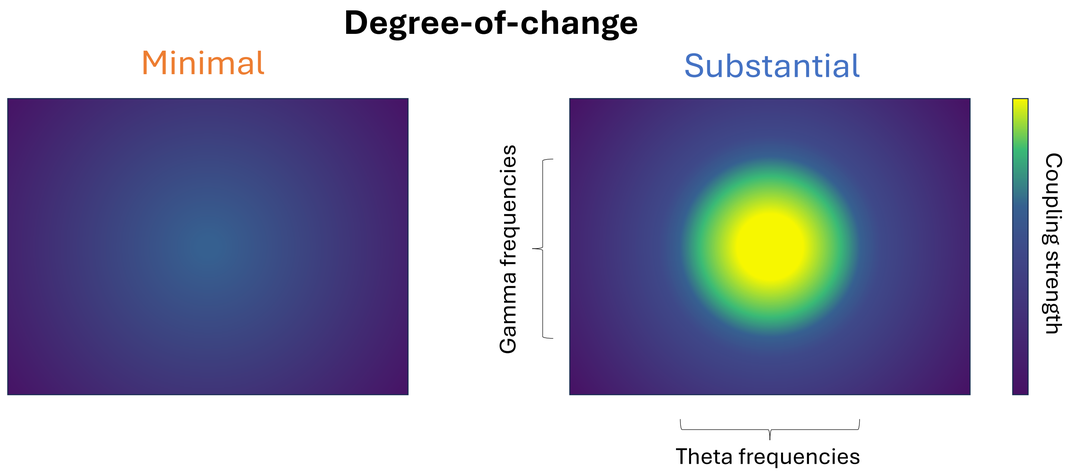
Analysis

7.2-second epoch from trial onset, encompassing both sentences
Electrode at T7
PAC calculated using a Driven Auto-Regressive (DAR) model[8]

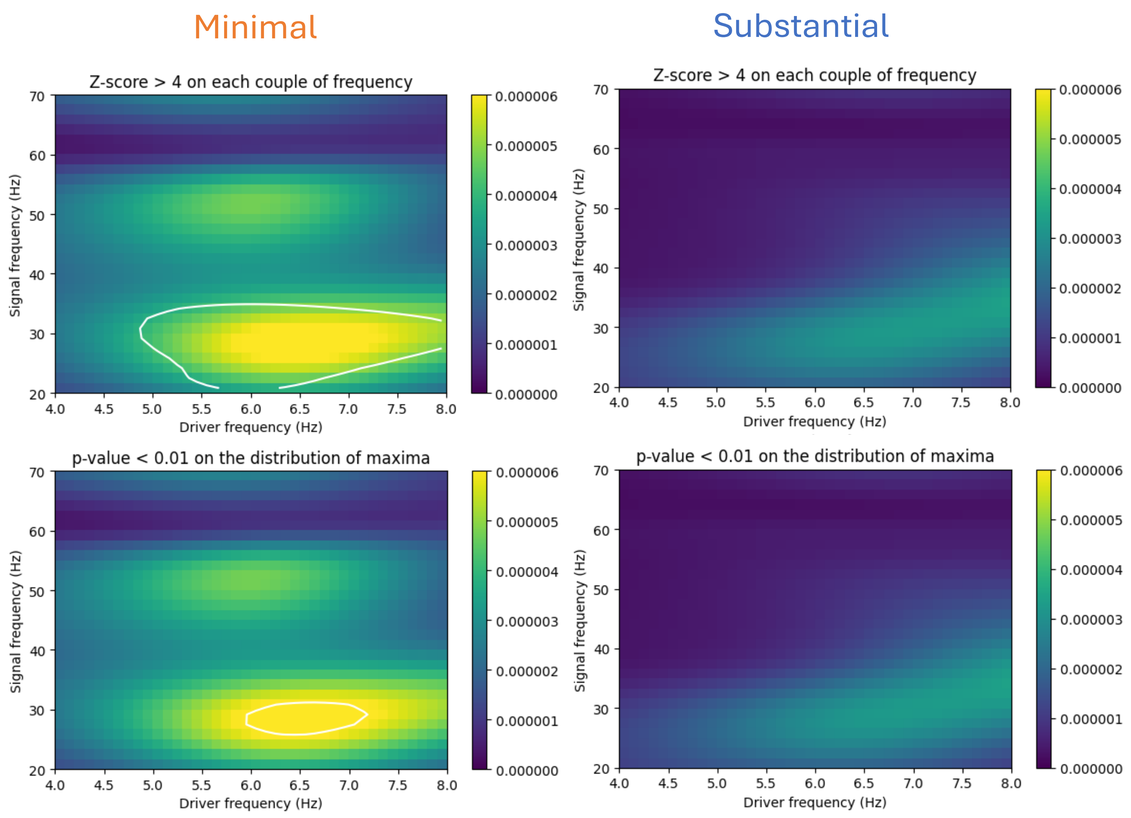


3. Results

Prediction: Substantial change condition has *more distinct object states* to maintain, hence might mean *more theta-gamma coupling*



Result: Significant theta-gamma PAC in the minimal change condition, but not in the substantial change condition



4. What's next?

Theta-gamma PAC in the minimal but not substantial state-change condition may reflect the increased cost of keeping two *similar* object-states distinct in working memory.

Before reaching a conclusion, we need to verify these secondary analysis results. We plan to run another follow-up study, but first, we seek more confidence in the methodology.

Among the questions to think about:
Multiple methods are available for PAC – which is the most suitable?
PAC method for contrasting two conditions (vs comparing against the null)?

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