# Neurodynamics of Working Memory Gating

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## WM Gating Function in PFC

### Introduction

Updating, maintenance, and recall of information in working memory (WM) may be supported by gates that control input and output of information. The goal of this research is to elucidate neurophysiological features underlying the cognitive functions of selective gating.

Hypothesis: WM gating mechanisms may be facilitated in PFC by neural ensemble states corresponding to oscillatory burst events recorded in local field potentials

Aim: To test time resolved electrical potentials from intracranial PFC recordings during a WM gating task

Patients: Recordings come from human subjects with intractable epilepsy who were implanted with subdural grid electrodes or depth electrodes as part of a preoperative procedure.

IR48: The presented results come from a patient with subdural grids covering frontal gyrus and medial-frontal regions.

### Gating Task

Hierarchical Rule Task

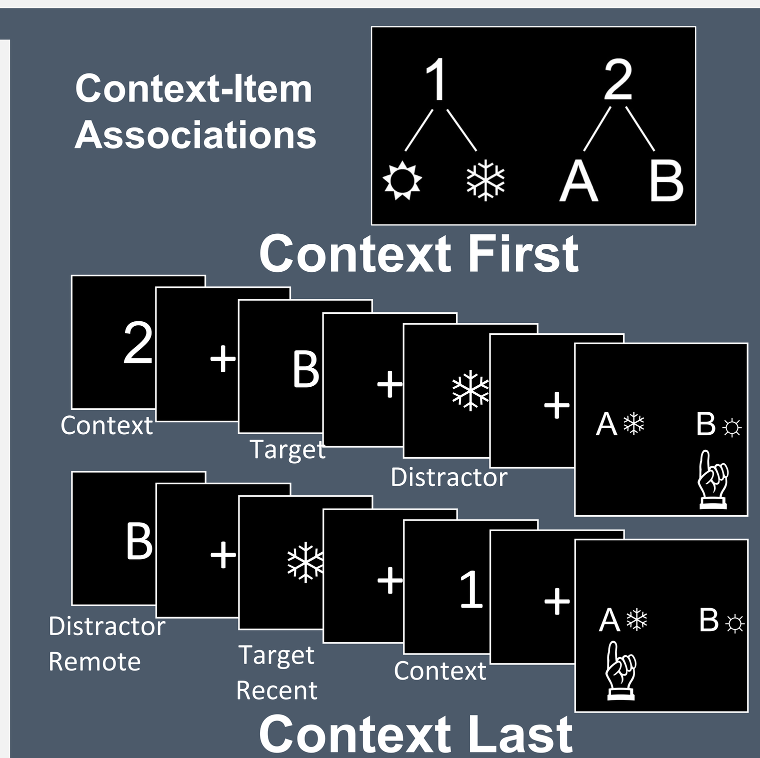
In each trial subjects are presented one context and two items in sequence (order varies). After the sequence subjects choose which context-relative item was presented in the sequence.

Input gating strategy

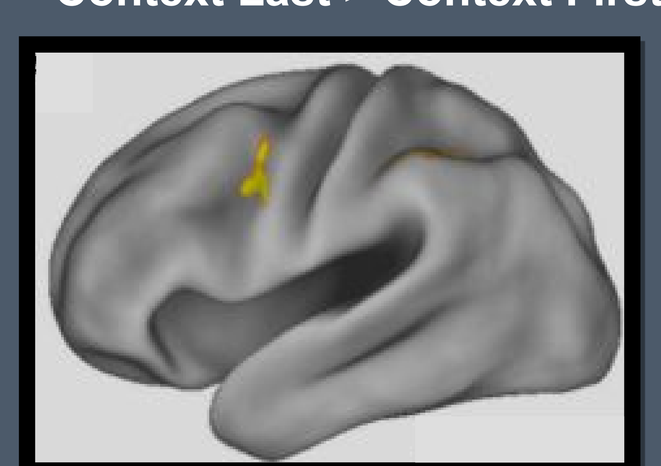
When the **context** is presented first, subjects are able to selectively encode the **target** while ignoring the **distractor**.

Output gating strategy

When the **context** is presented last, subjects must encode **both items** so that they can retroactively choose the *target* once the context is known.




**Context Last > Context First**



Chatham et al. 2014

### Regions of Interest

prePMD: fMRI evidence has linked prePMd with **output gating** specifically (Chatham et al. 2014).

SMA: Medial frontal regions form a network with corresponding lateral PFC regions during cognitive control tasks.

## Oscillations in Gating Framework

**Input gating** requires choosing relevant information to encode in working memory over distractors, likely manifesting through corticostriatal interactions (Chatham et al. 2014).

In PFC, rules used for **top down control** may be encoded by synaptic changes that arise through short-lived **synchronization of rule-selective ensembles**. (Lundqvist et al. 2016).

Emergent physiological properties of such ensembles include **beta oscillations during default states** and **gamma oscillations during active states .**

### Predictions

In **target** condition, we expect selective networks to enter **active states (gamma oscillations)** in order to encode an item into WM.

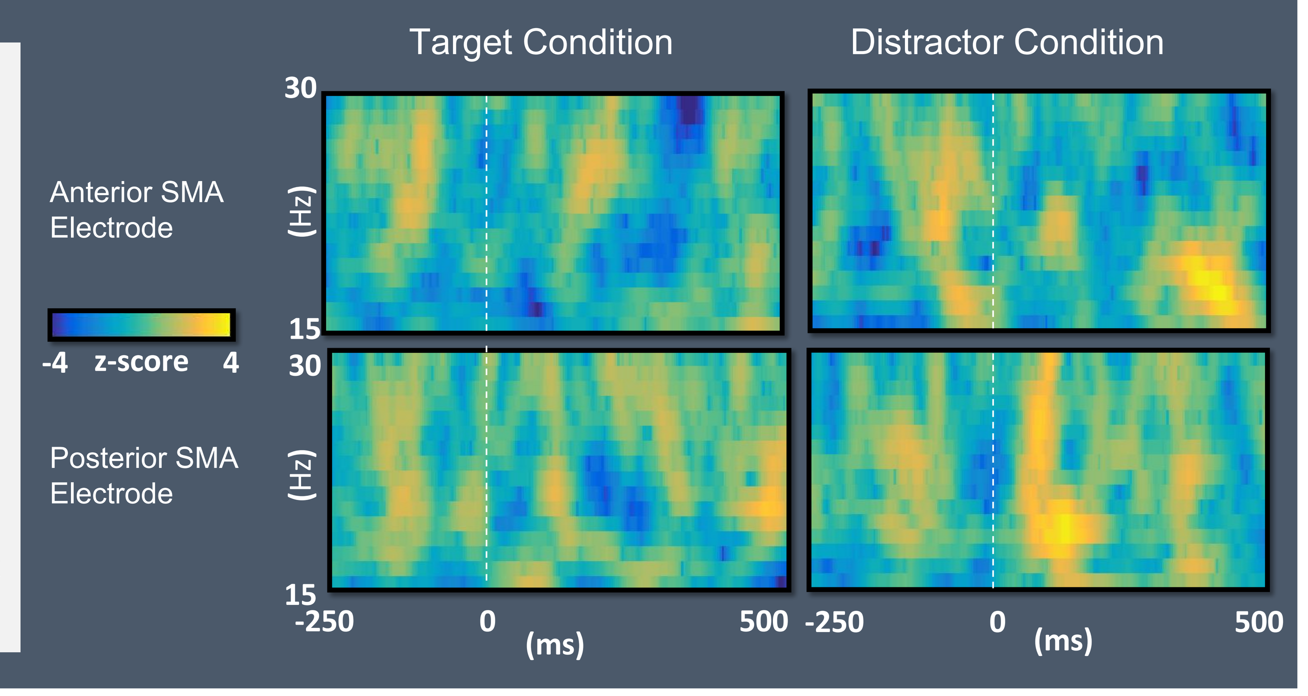
In **distractor** condition, we expect selective networks to maintain **default states (beta oscillations)** as an item is not encoded into WM.

## Shortcomings of Event-Related Power Spectra

Event-locked spectra comparisons of beta yielded differential mean power in **target** and **distractor** within some electrodes. However, regional averages of instantaneous power and omnibus analyses of power spectra were inconclusive.

Low/medium spectral power may obfuscate event-averaged spectral analyses. Evidence suggests neurophysiological beta oscillations may not be gradient features but **high-power events** that are formed by **strong distal drive synchrony** in pyramidal dendrites. (Sherman et al. 2016).

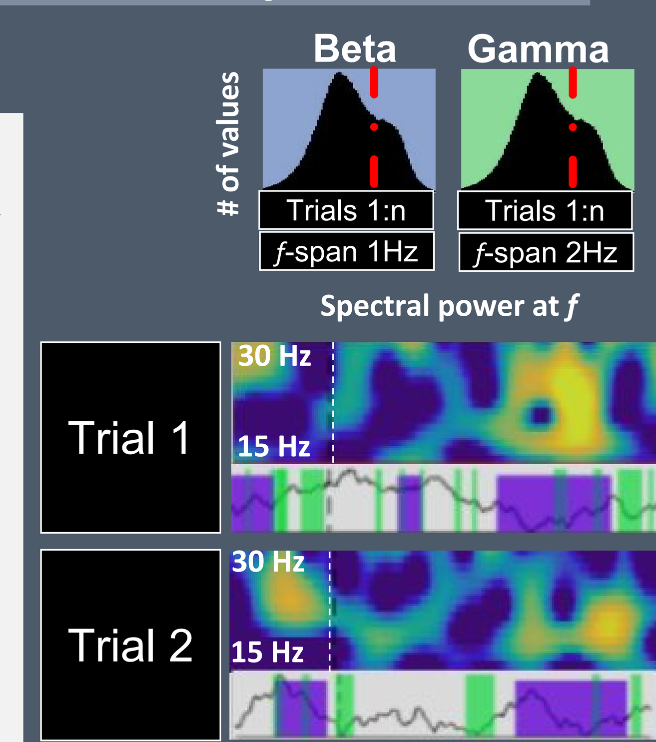
**Transient oscillatory events** may be misrepresented as sustained activity in the event-averaged spectrum (Feingold et al. 2015).




## Burst Analysis

### Burst Detection

We defined oscillatory bursts as intervals when single-trial spectral power exceeded 1.25 SDs above the log distribution of power from all non-choice events from -250 to 750 ms in three or more consecutive frequency bins for at least 1 cycle.

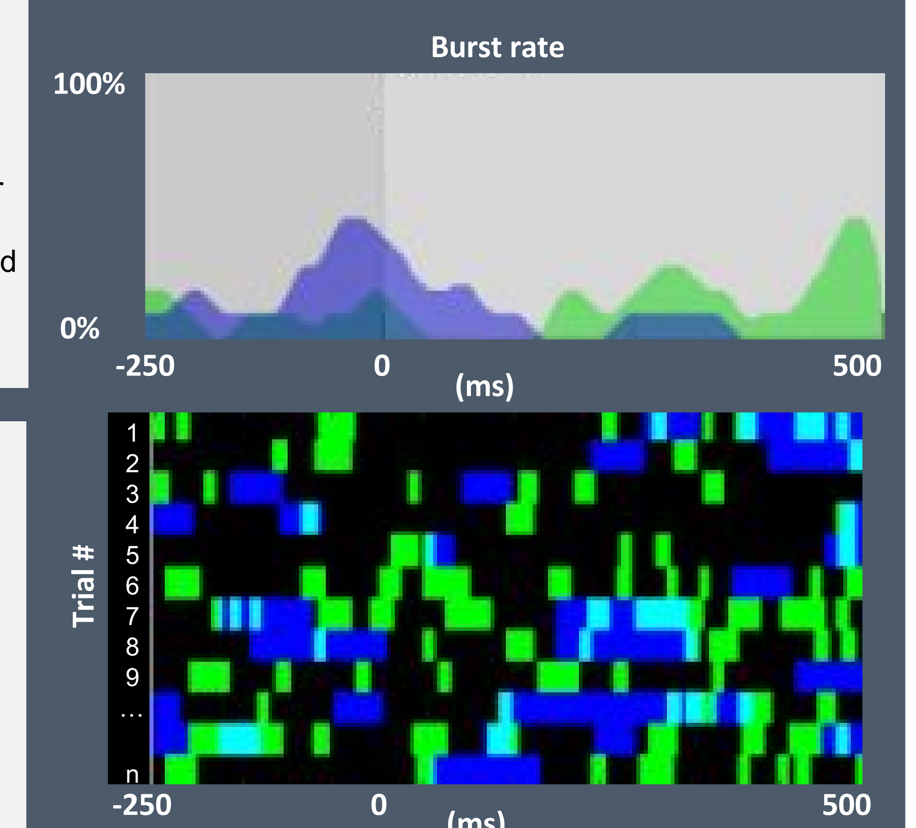



### Burst Rate

Average across same condition events to determine an event-locked probability function for oscillatory bursts. Bursts can be summed as probability instead of a binary event to similar effect

### Burst Pattern

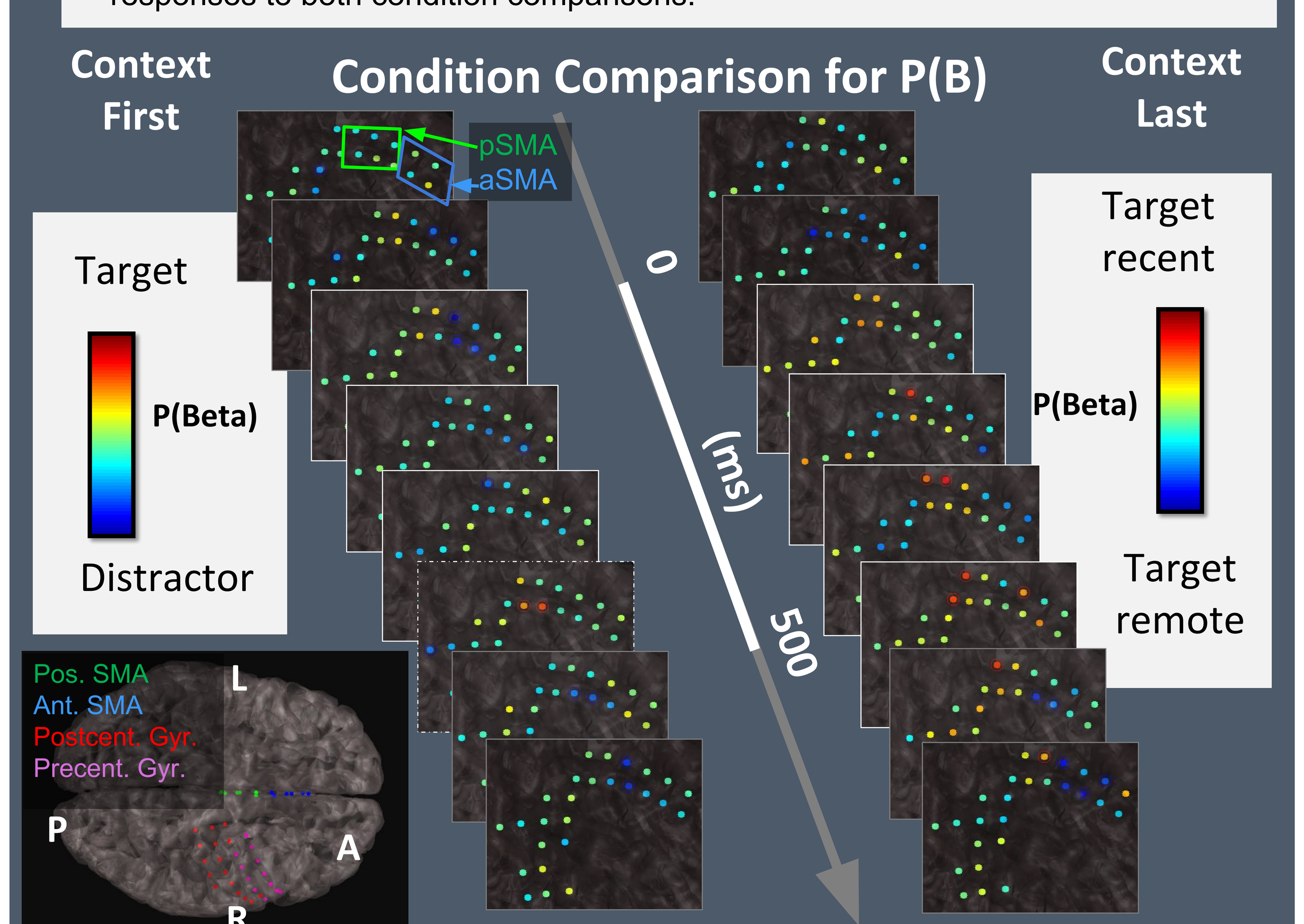
Preserve within-trial interactions between bursts. This allows us to treat burst features as a point process across time, electrodes, and/or conditions.




## Beta Dynamics in SMA

**Patient IR48**

- Anterior and posterior SMA exhibits **gradient response** to both trial comparisons
- Precentral and Postcentral gyrus have relatively **stable and neutral** beta rate responses to both condition comparisons.

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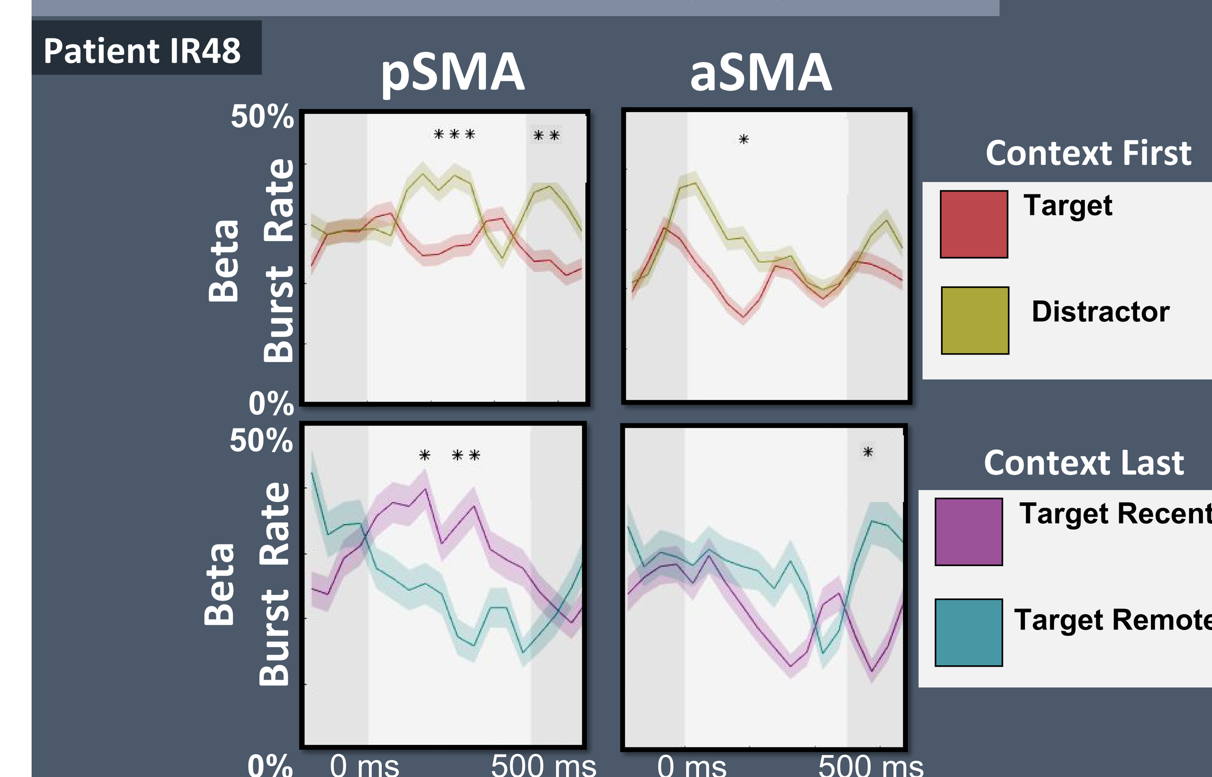
## Conclusions

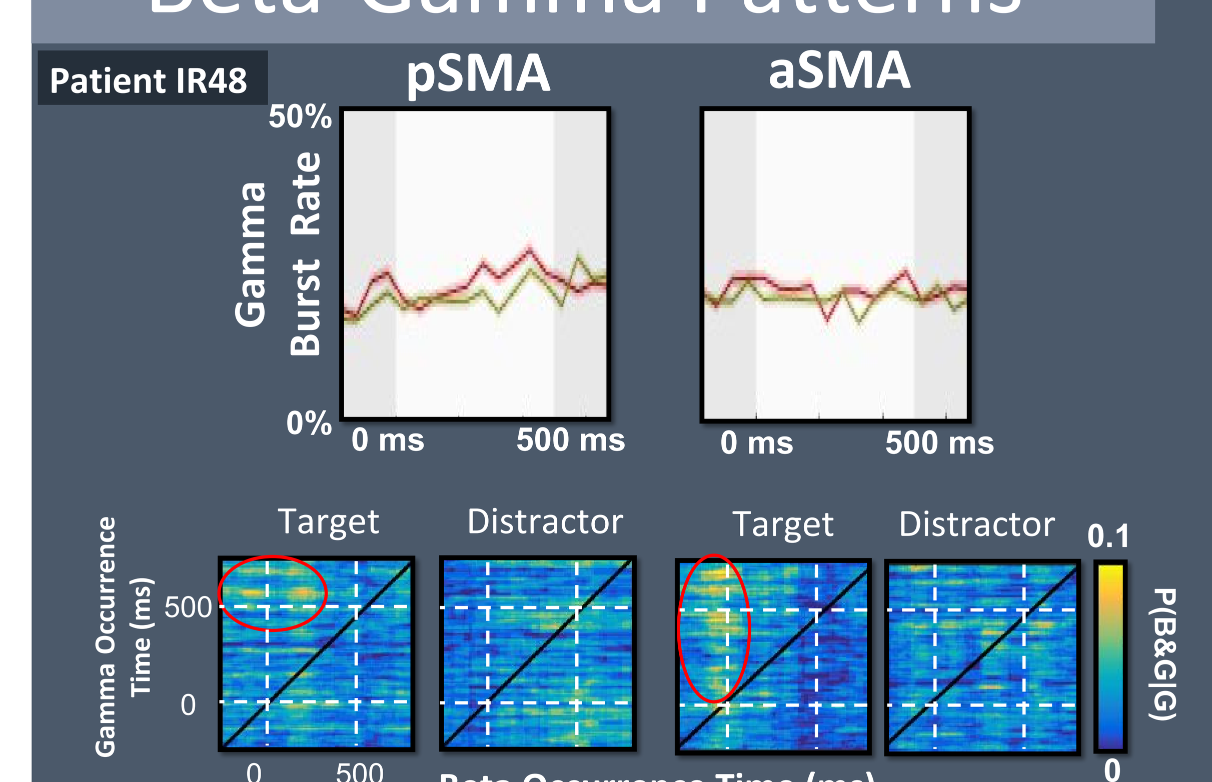
- In *input gating* scenarios, **beta rates increased for *distractor* items**
  - May reflect inhibition of encoding of the distractor item into working memory (Wessel et al. 2016).
  - May reflect maintenance of default states for rule-selective ensembles (Lunqvist et al. 2016).
- In *output gating* scenarios, **beta rates increased for target-recent trials**. This finding suggests that the ordering of item encoding into WM has functional importance for how WM contents are retroactively selected.
- **Co-occurrence of beta and gamma** in *target* conditions supports the hypothesis that task-relevant ensemble states dynamically change to selectively gate information into WM.

## Beta Burst Rates




- *Distractor* condition contained increased beta burst rates, relative to *target* condition. Both pSMA and aSMA demonstrated increased rates but at different intervals.
- *Target-recent* trials contain increased beta burst rates for a large interval in pSMA but not aSMA.

## Beta-Gamma Patterns




- No significant differences were observed between gamma burst rates across condition comparisons across all parameterizations (SD [0,2], cycles [4,10])
- Early beta oscillations co-occur with late gamma oscillations during *target conditions* but not *distractor conditions.* The co-occurrences tend to happen for beta events near stimulus-onset and gamma events near stimulus off-set.