Sampling of time intervals in rhythmic sound sequences: a Beta version

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Outline

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A. Introduction

Timing in the brain

Time is a fundamental aspect of brain function.
But no dedicated sensory apparatus for encoding time.

Natural stimuli like speech and music contain rich temporal structure.

Listening to rhythms with a strong beat synchronizes our movements.

Oscillatory signals support distinct brain functions and coordinate information transfer underlying various perceptual, cognitive and sensorimotor tasks.

How do oscillatory signals particularly in the beta range (12-30 Hz) influence perception and estimation of temporally structured events?

Beta activity

Beta linked to the motor system, involved in overt movement and motor imagery. Beta power decreases before and during movement followed by a rebound.

Beta activity in motor areas is related to the maintenance of the current state of the network as well as the expectancy of forthcoming events (Engel & Fries, 2010).

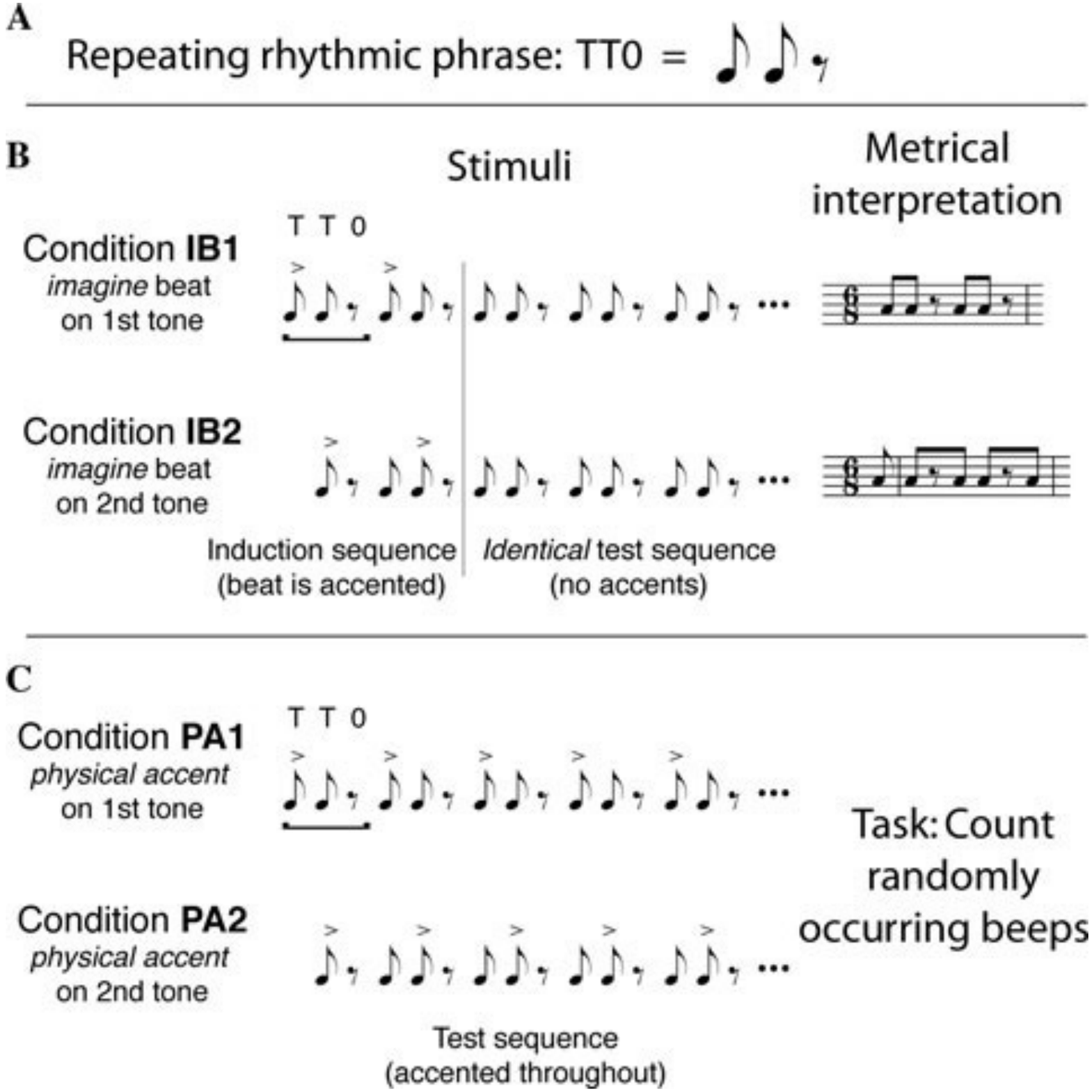
Beta mediates long-distance cortical coupling (Kopell et al., 2000)

Nested coupling between beta & gamma or delta & beta oscillations may facilitate cross-modal interaction between sensory channels that process information on different time scales.

What is the precise role of beta oscillations in non-motor circuits underlying cognitive functions like timing and beat perception?

B. Role of beta oscillations in timing

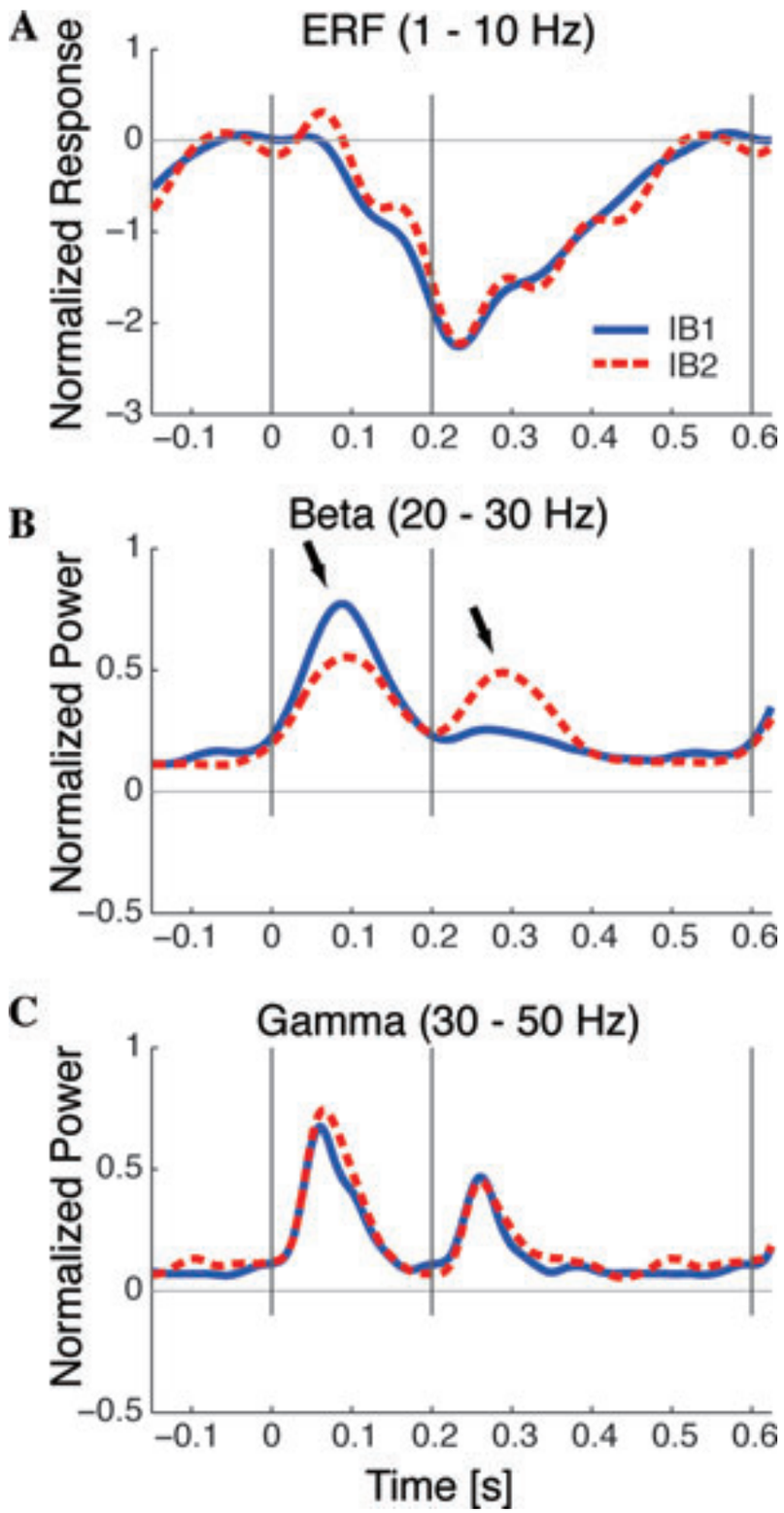
Iversen et al. 2009



Human MEG

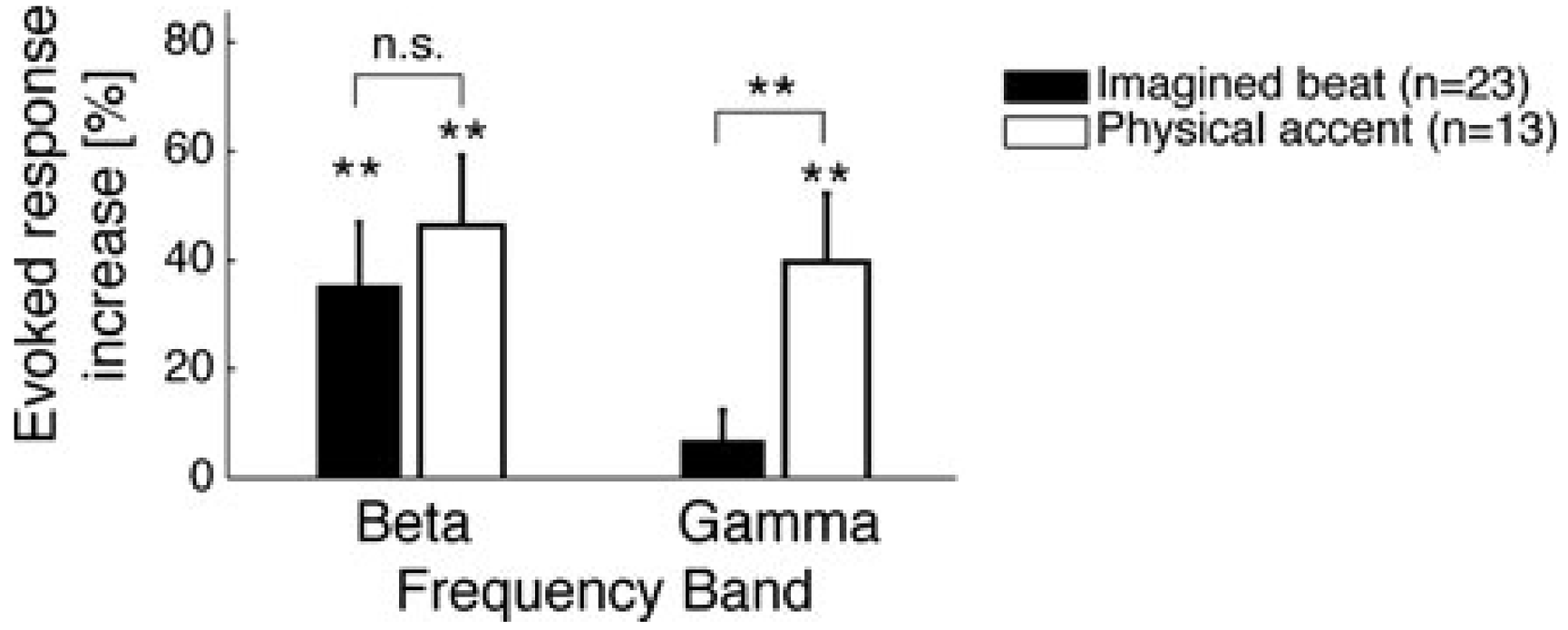
Ann. NY Acad. Sci.

Iversen et al. 2009



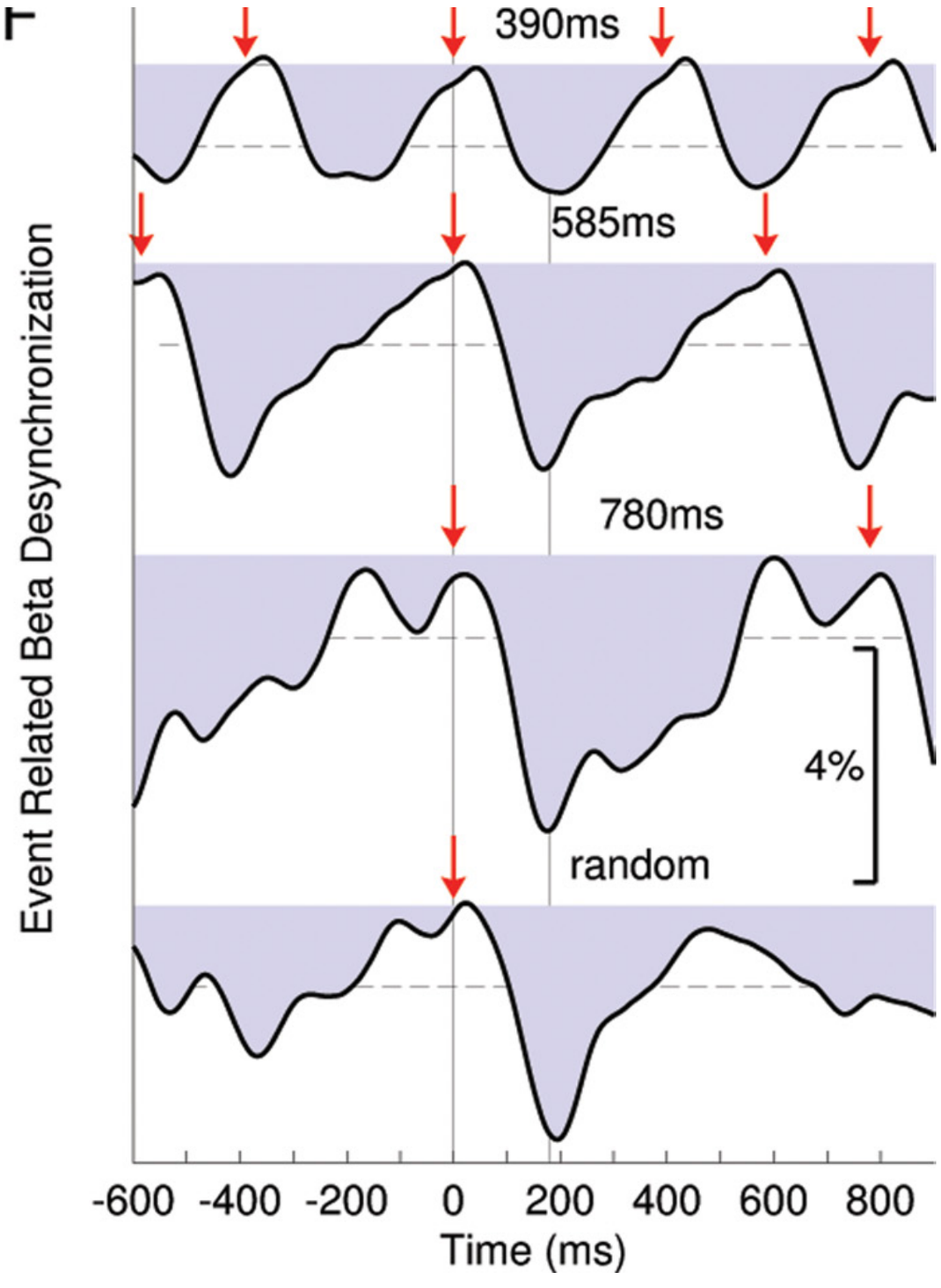
Human MEG **Evoked beta** **Ann. NY Acad. Sci.**

Iversen et al. 2009



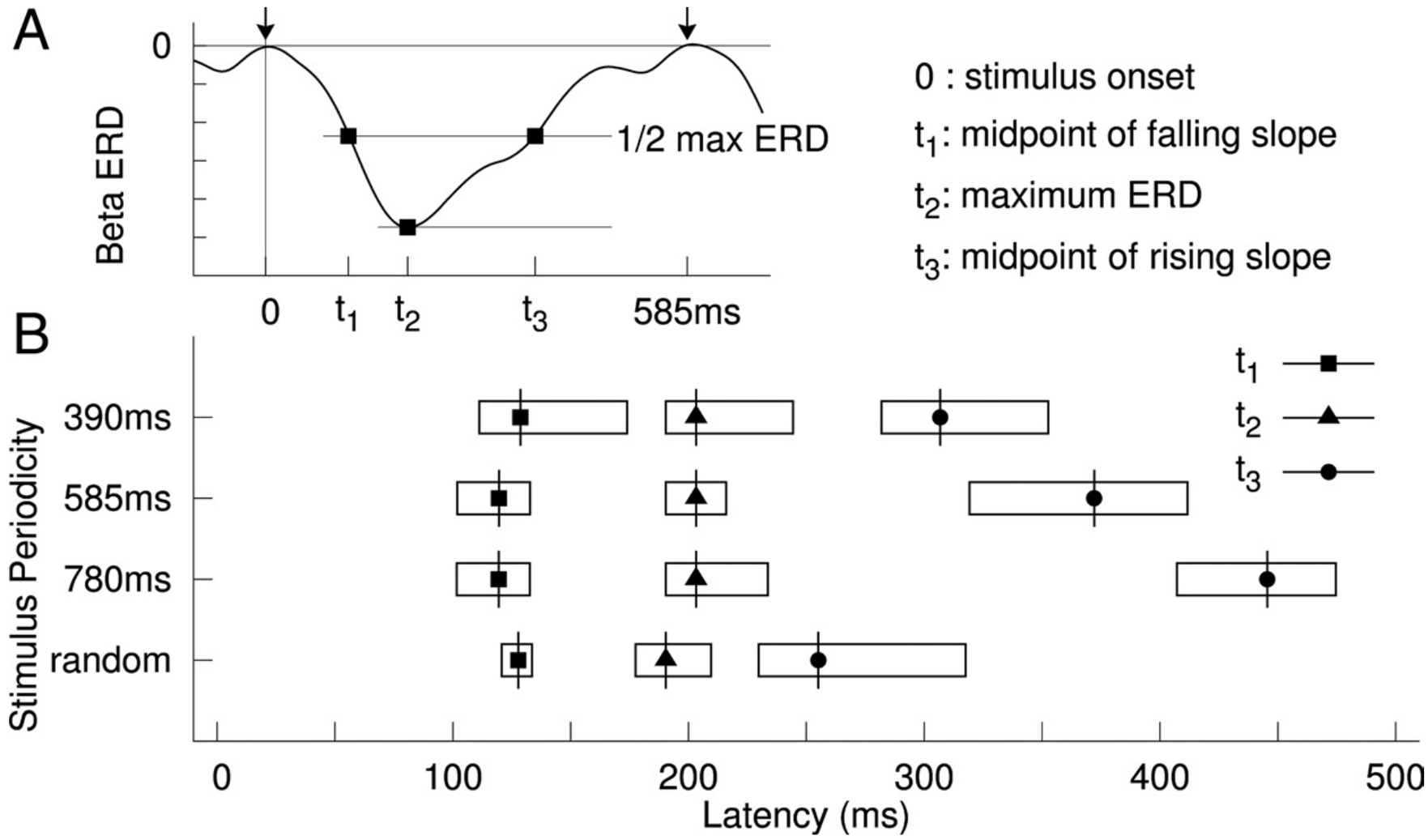
Human MEG **Evoked beta** **Ann. NY Acad. Sci.**

Fujioka et al. 2012



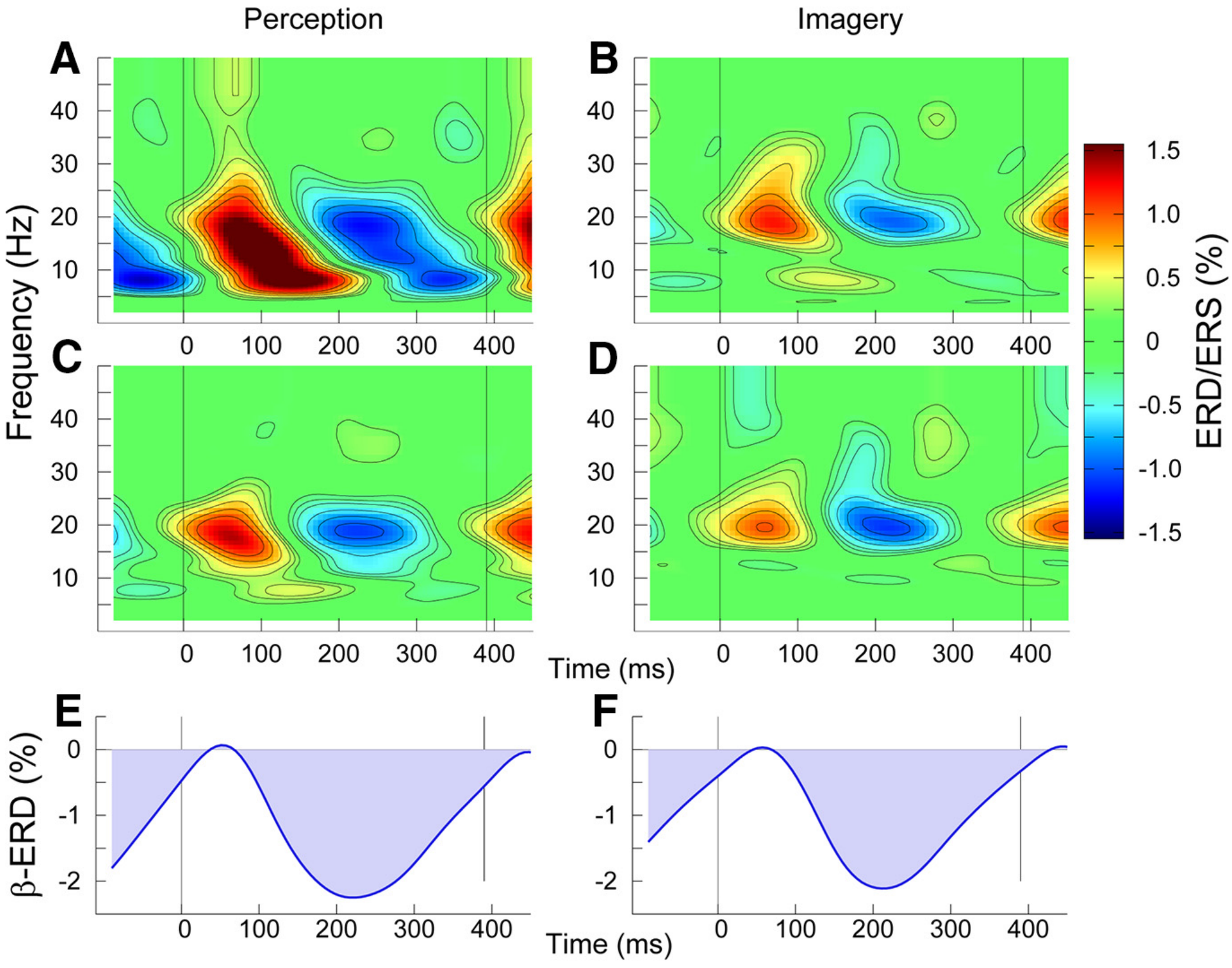
Human MEG **Induced beta** **J. Neurosci.**

Fujioka et al. 2012



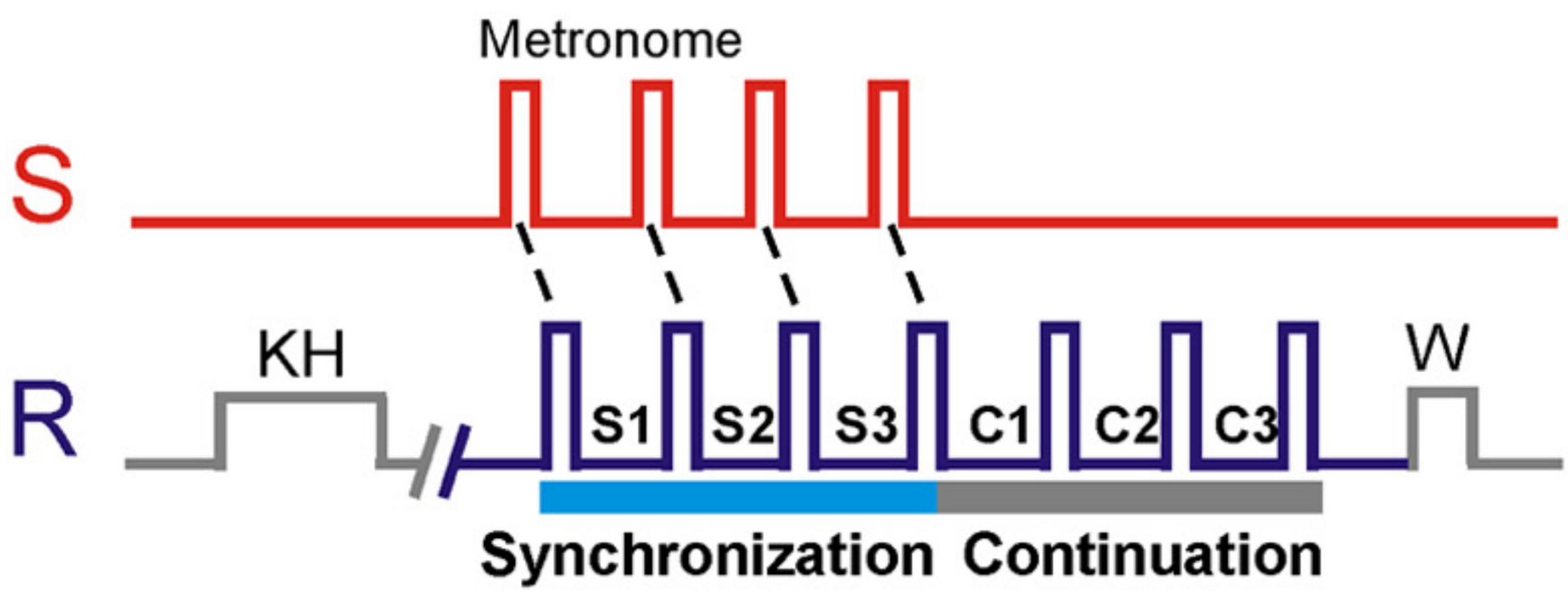
Human MEG **Induced beta** **J. Neurosci.**

Fujioka et al. 2015



Human MEG **Induced beta** **J. Neurosci.**

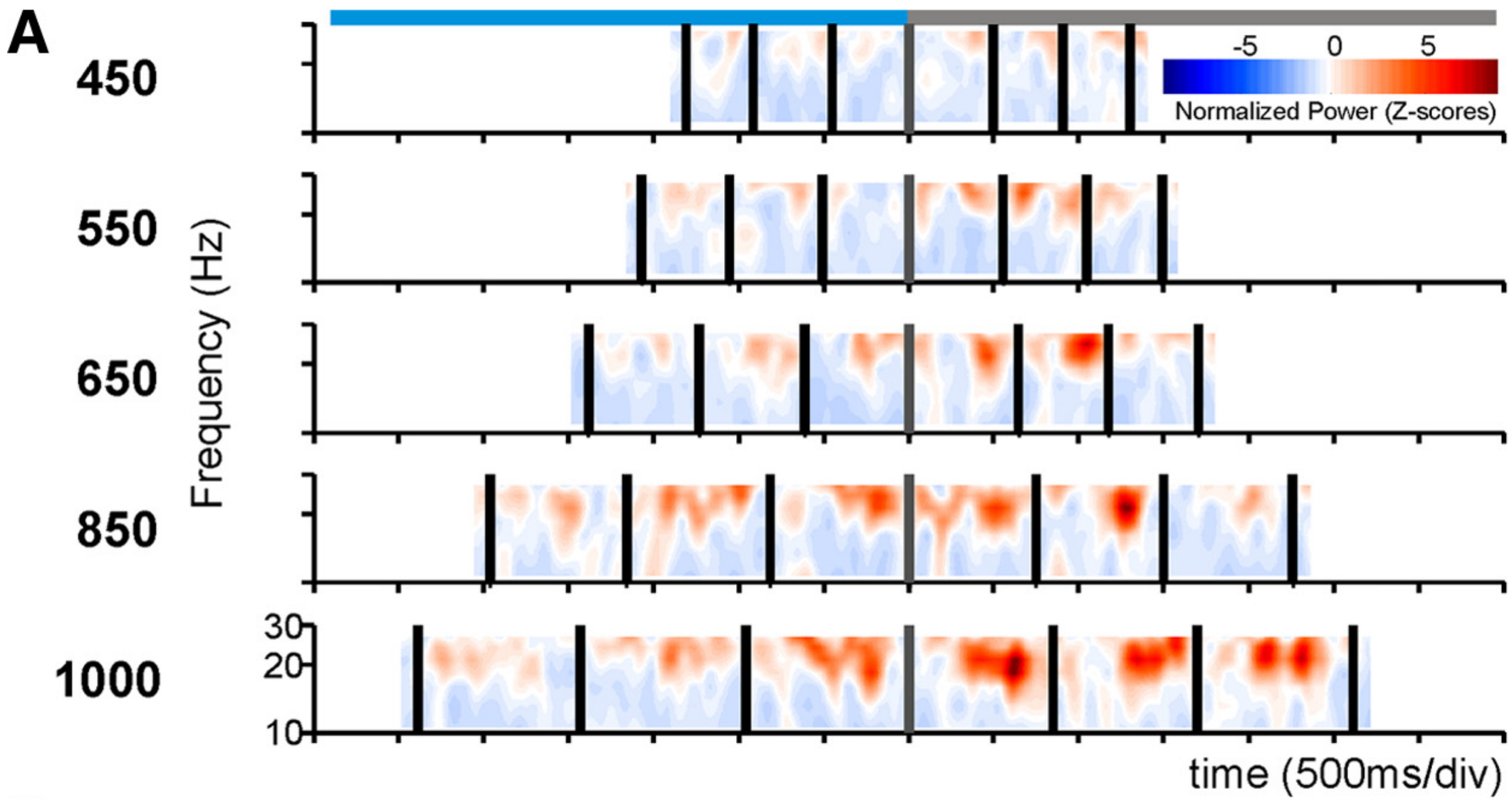
Bartolo et al. 2014



Macaque Electrophysiology

J. Neurosci.

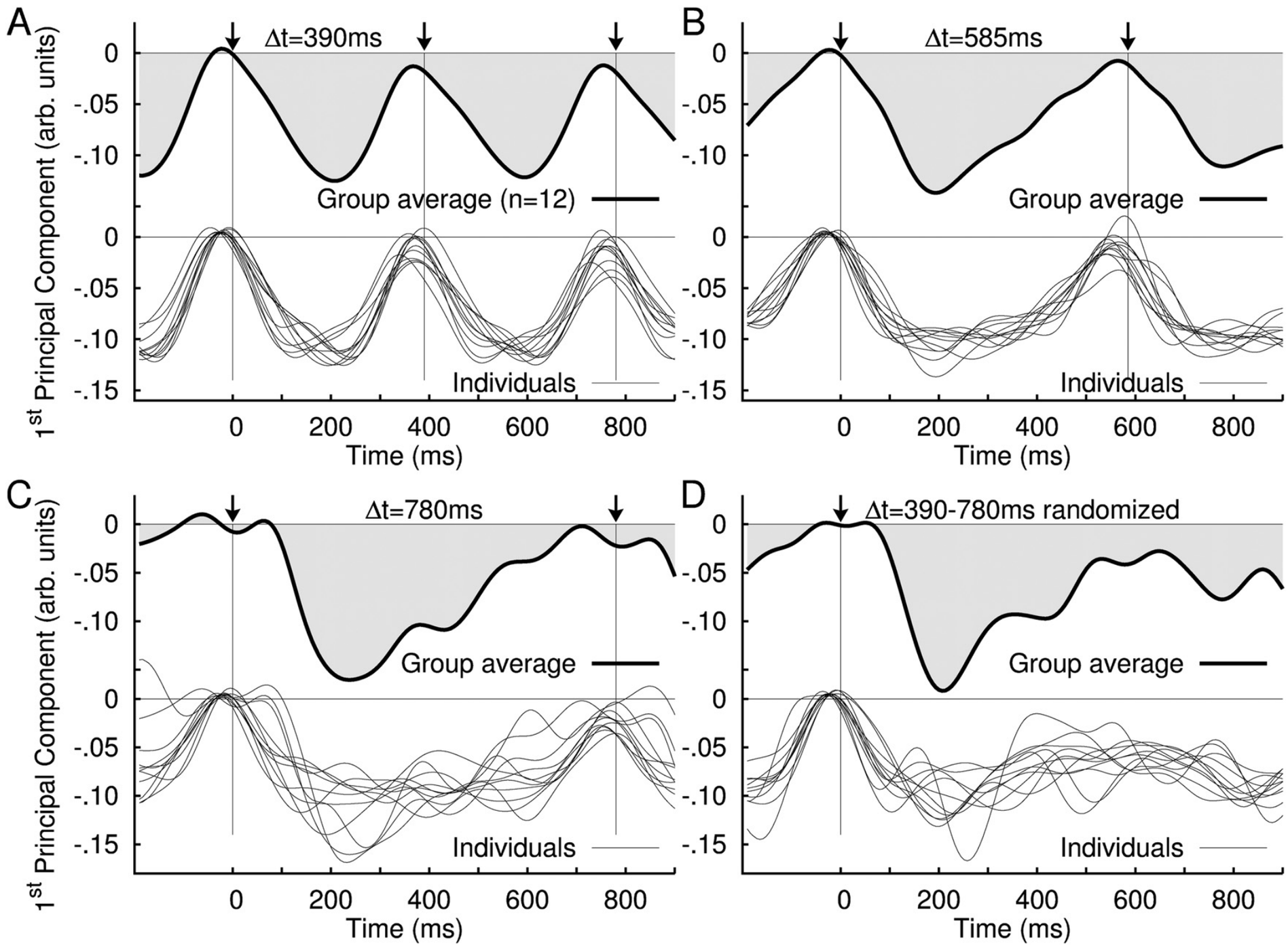
Bartolo et al. 2014



Macaque Electrophysiology **Field potentials** **J. Neurosci.**

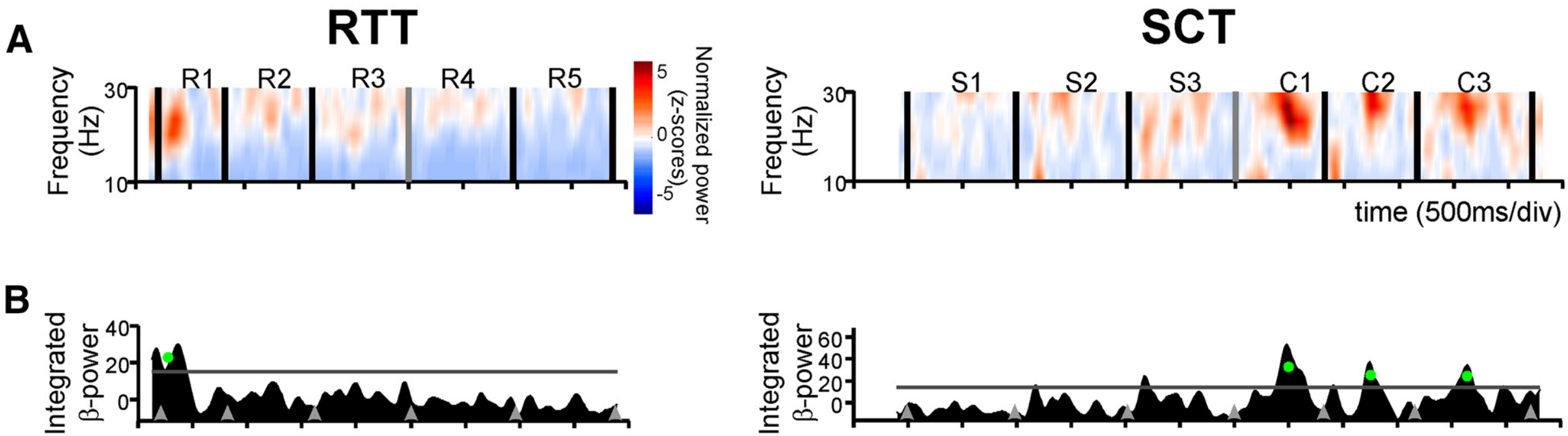
B1. Modulation of beta oscillations by temporal context

Fujioka et al., 2012



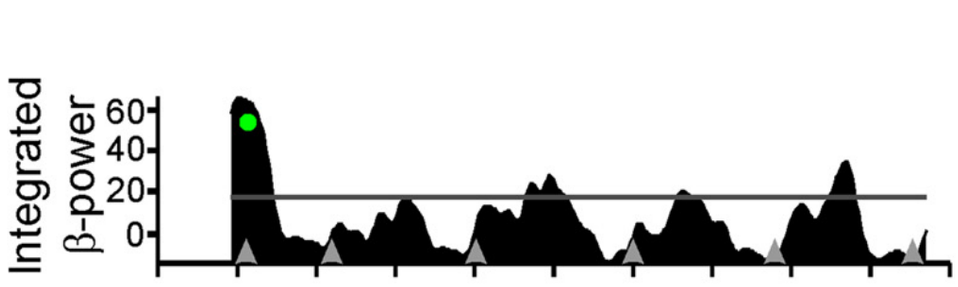
Human MEG **Induced beta** **J. Neurosci.**

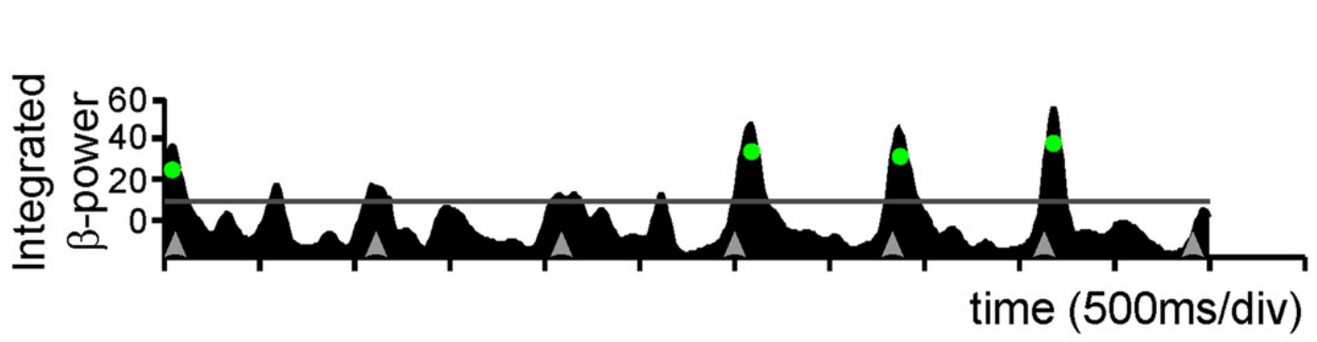
Bartolo & Merchant, 2015



Macaque Electrophysiology **Field potentials** **J. Neurosci.**

Bartolo & Merchant, 2015





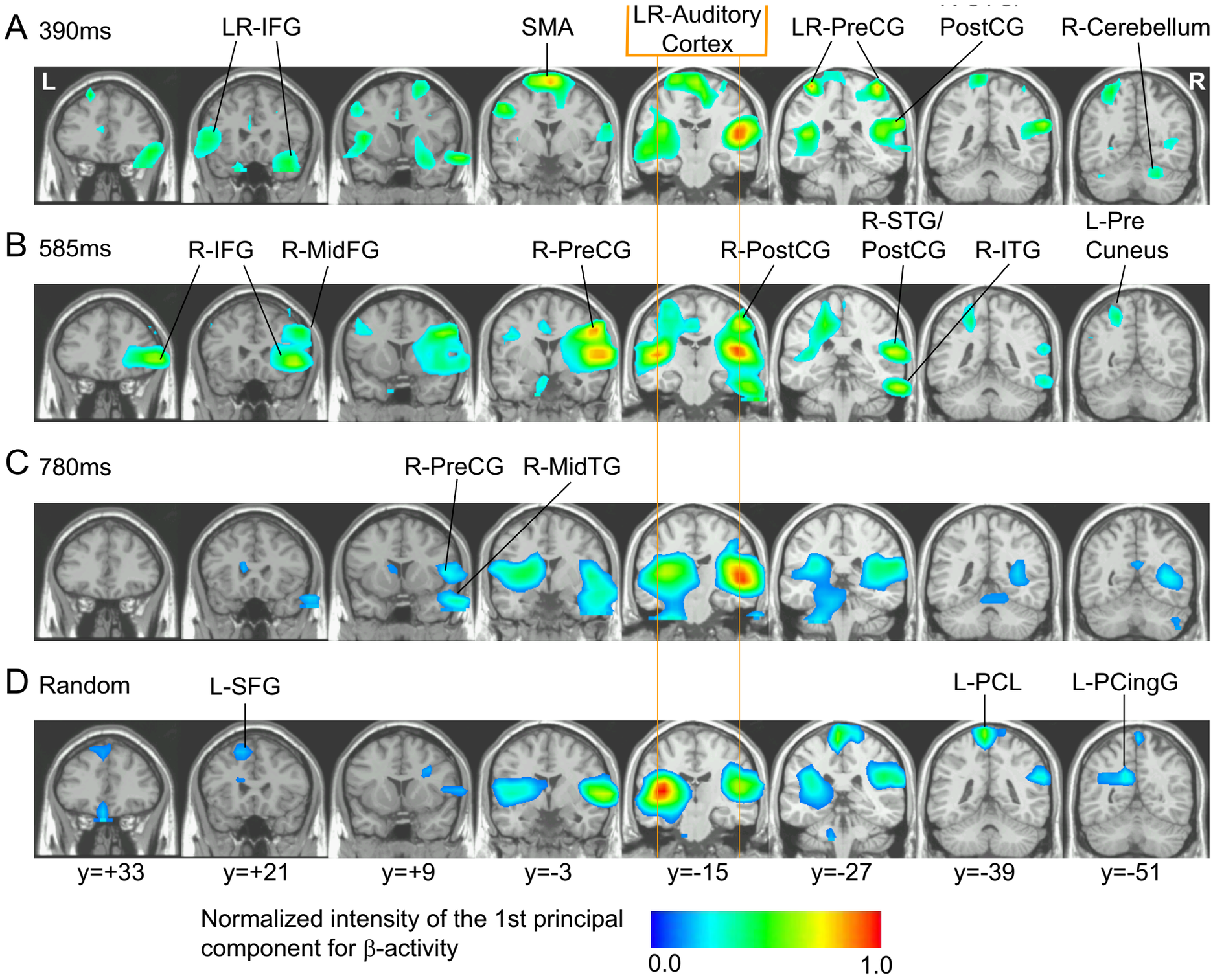
Macaque Electrophysiology

Field potentials

J. Neurosci.

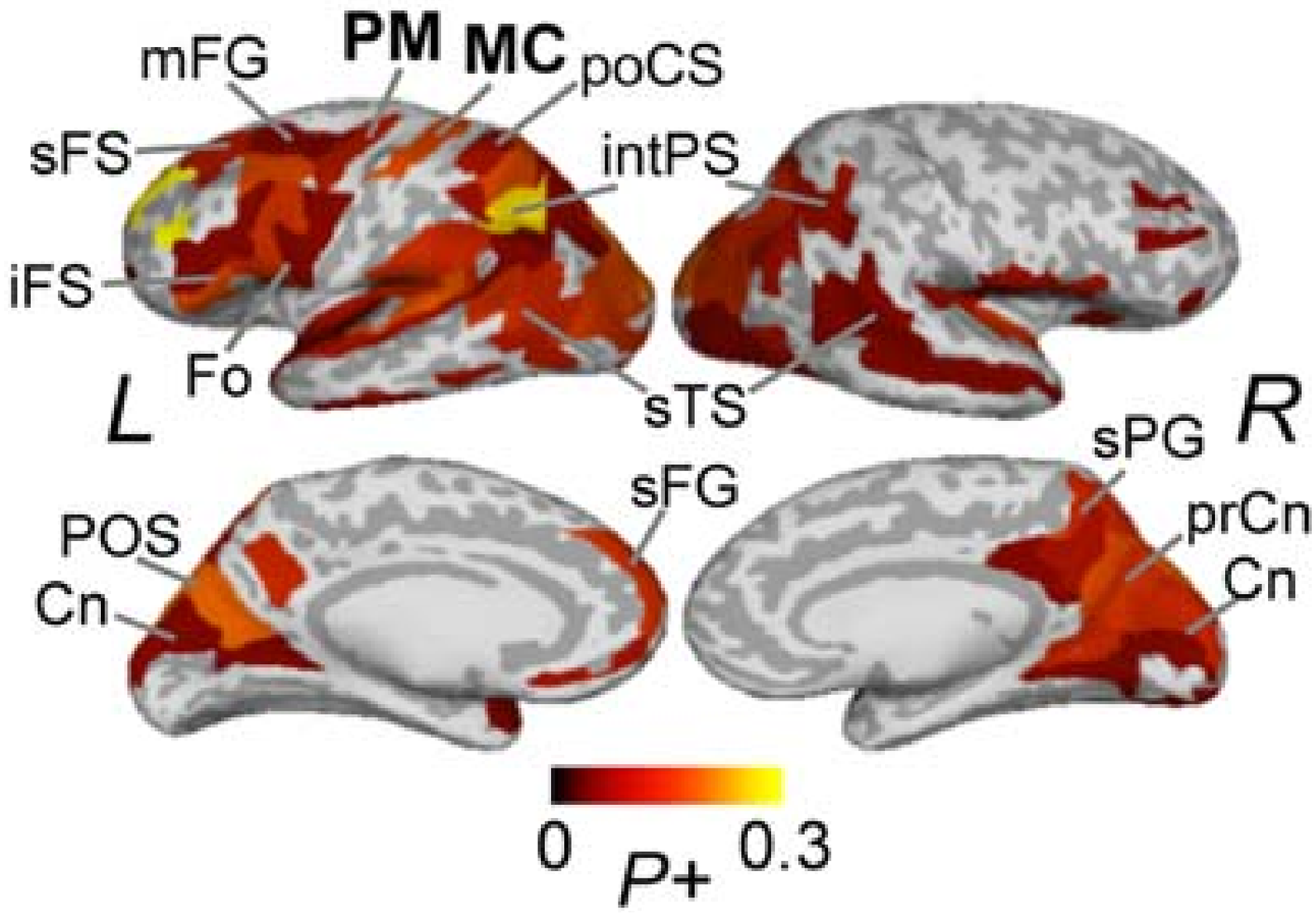
B2. Sources of beta modulation

Fujioka et al. 2012



Human MEG **Induced beta** **J. Neurosci.**

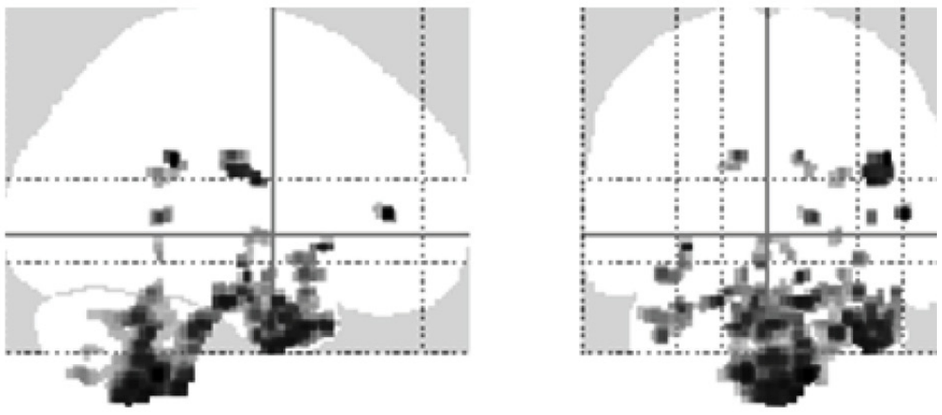
Kulasekhar et al., 2016



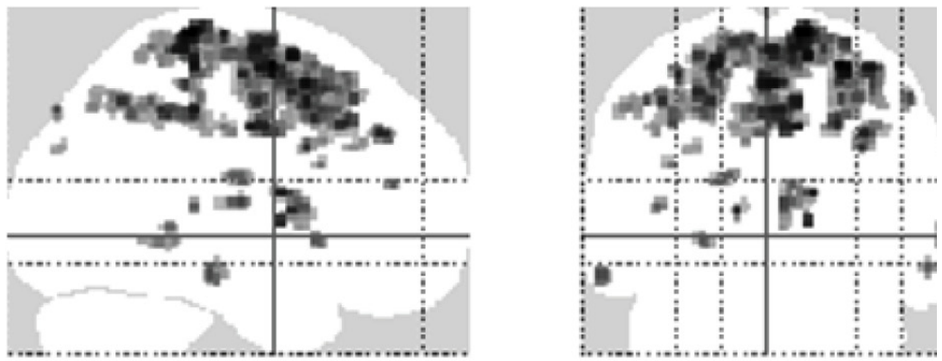
Human MEG **Evoked beta** **Hum. Br. Mapp.**

Teki et al., 2011

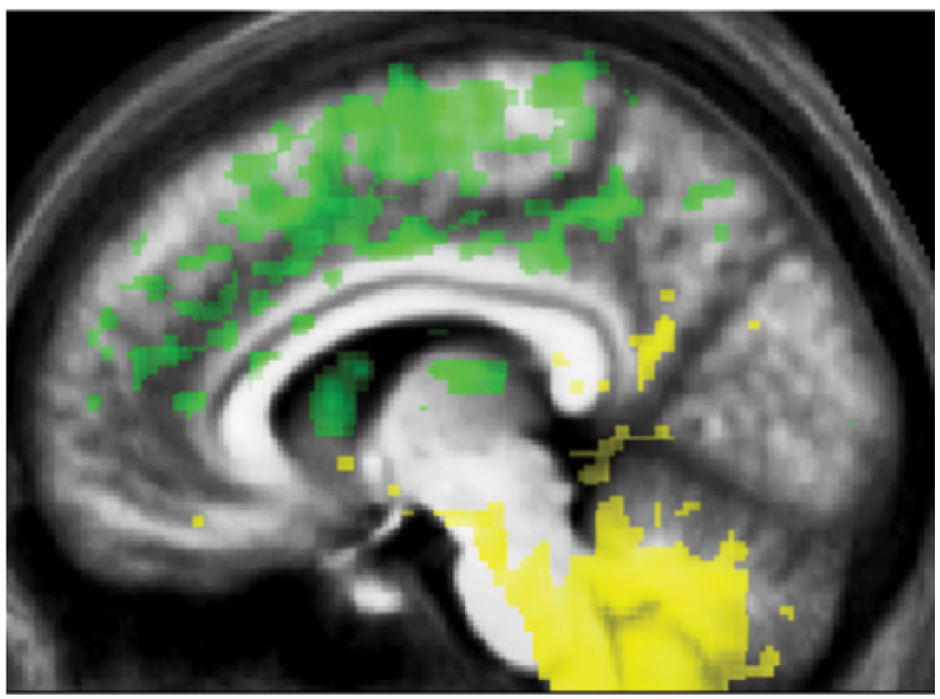
A Activations for absolute, duration-based timing



B Activations for relative, beat-based timing



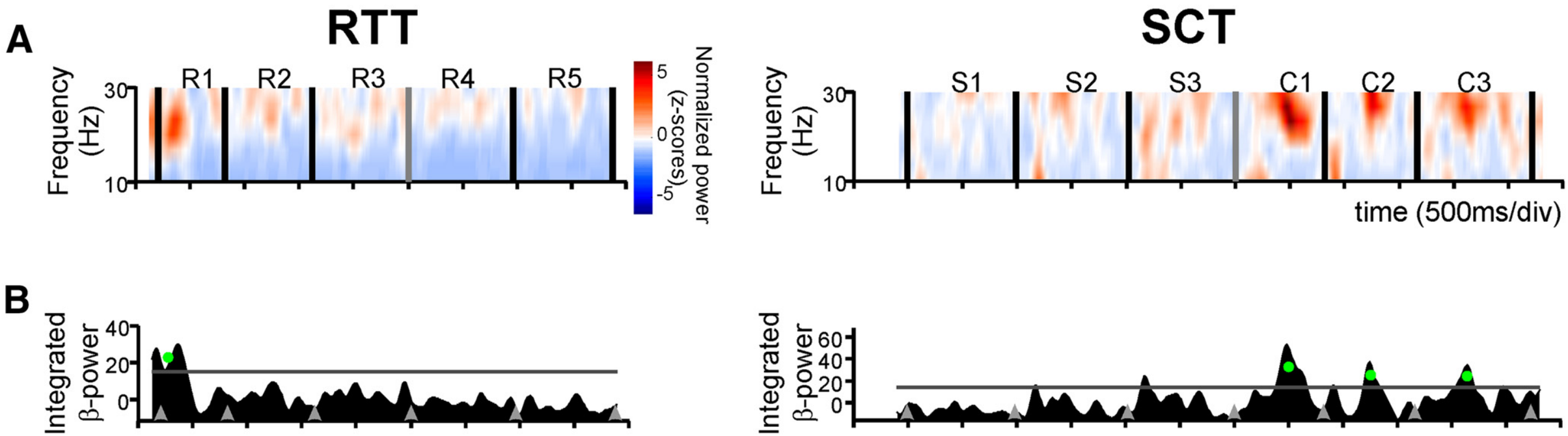
C Dissociation between absolute and relative timing



Human fMRI

J. Neurosci.

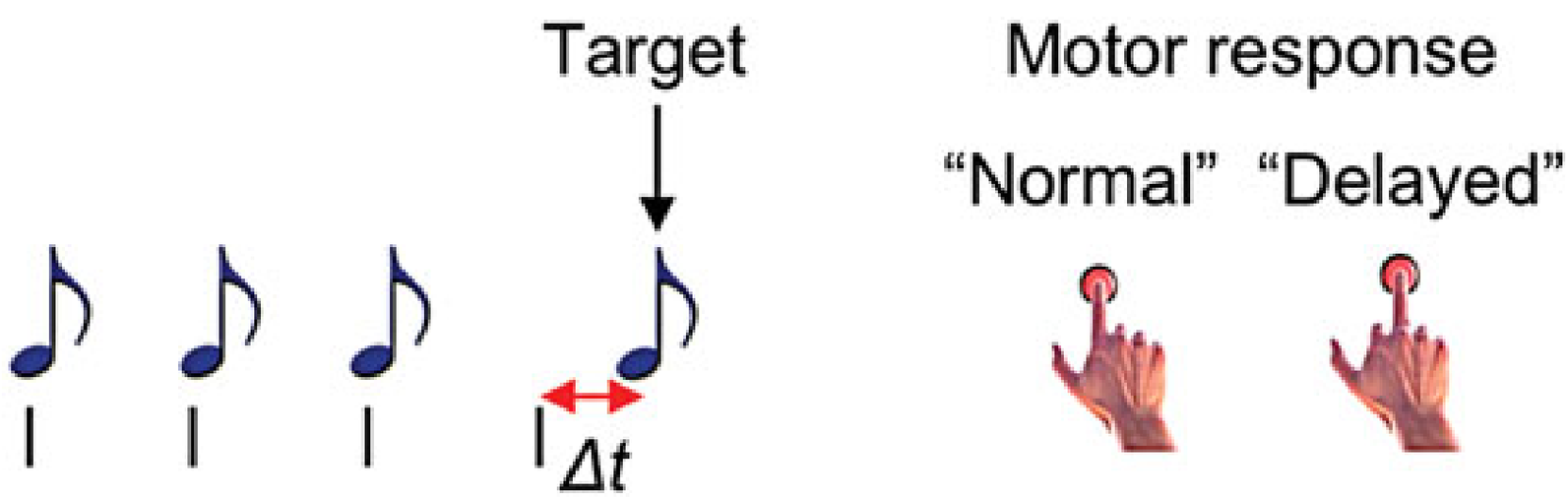
Bartolo & Merchant, 2015



Macaque Electrophysiology **Field potentials** **J. Neurosci.**

B3. Delta-beta coupling in timing

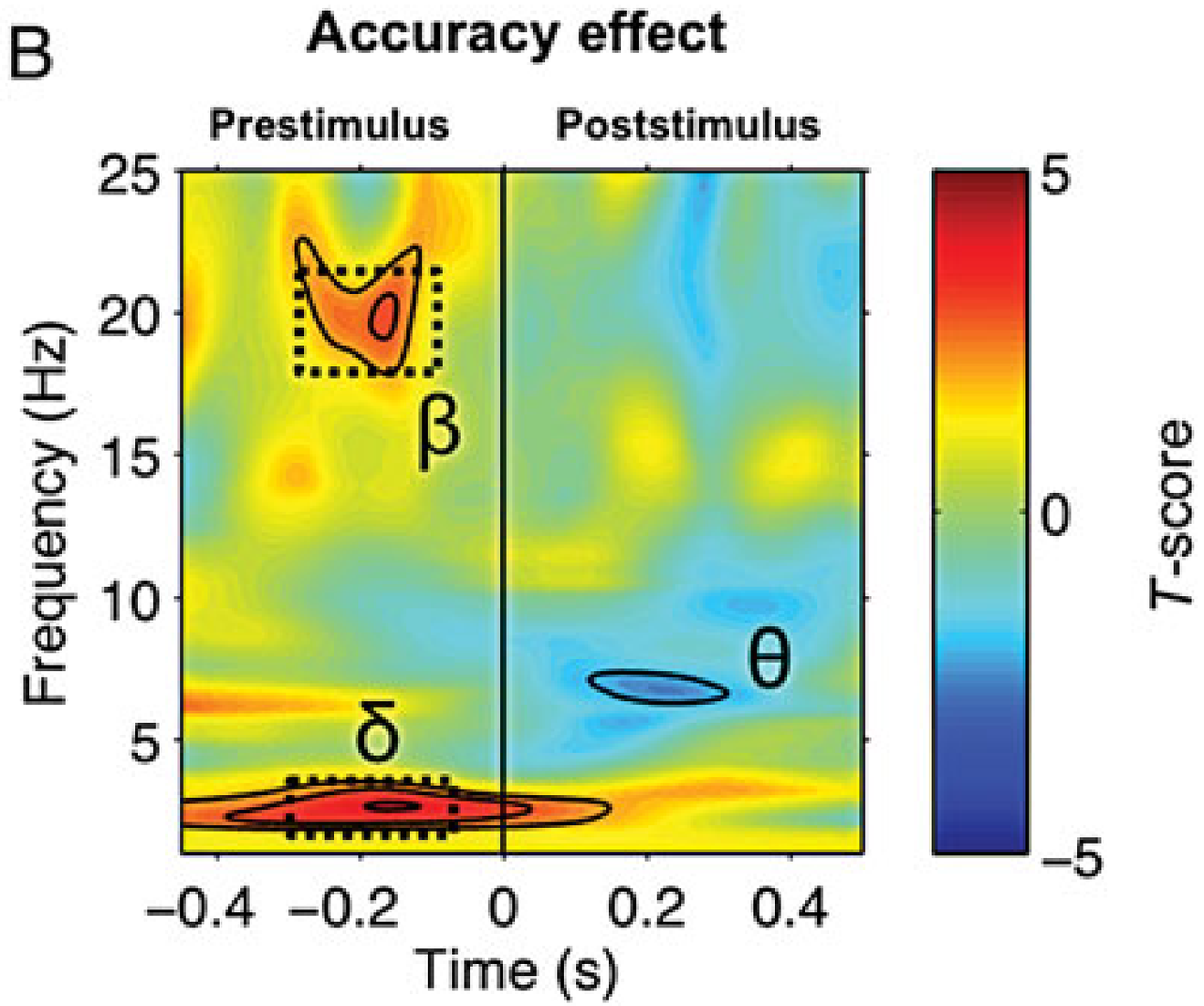
Arnal et al., 2014



Human MEG

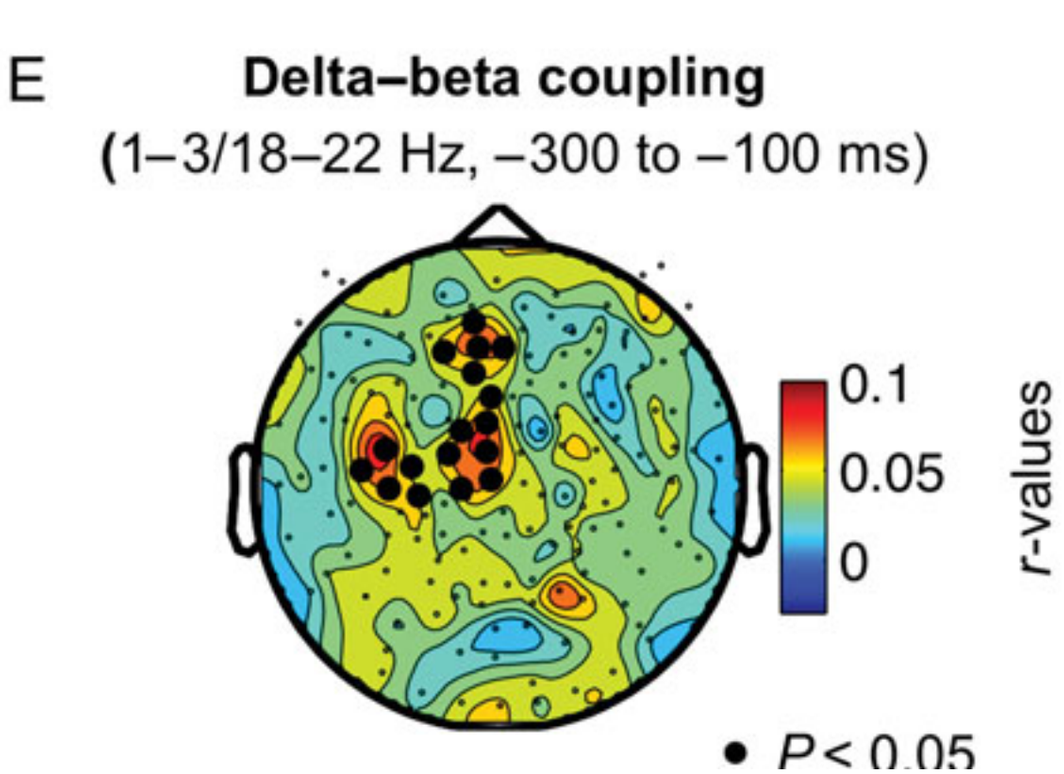
Cereb. Cortex

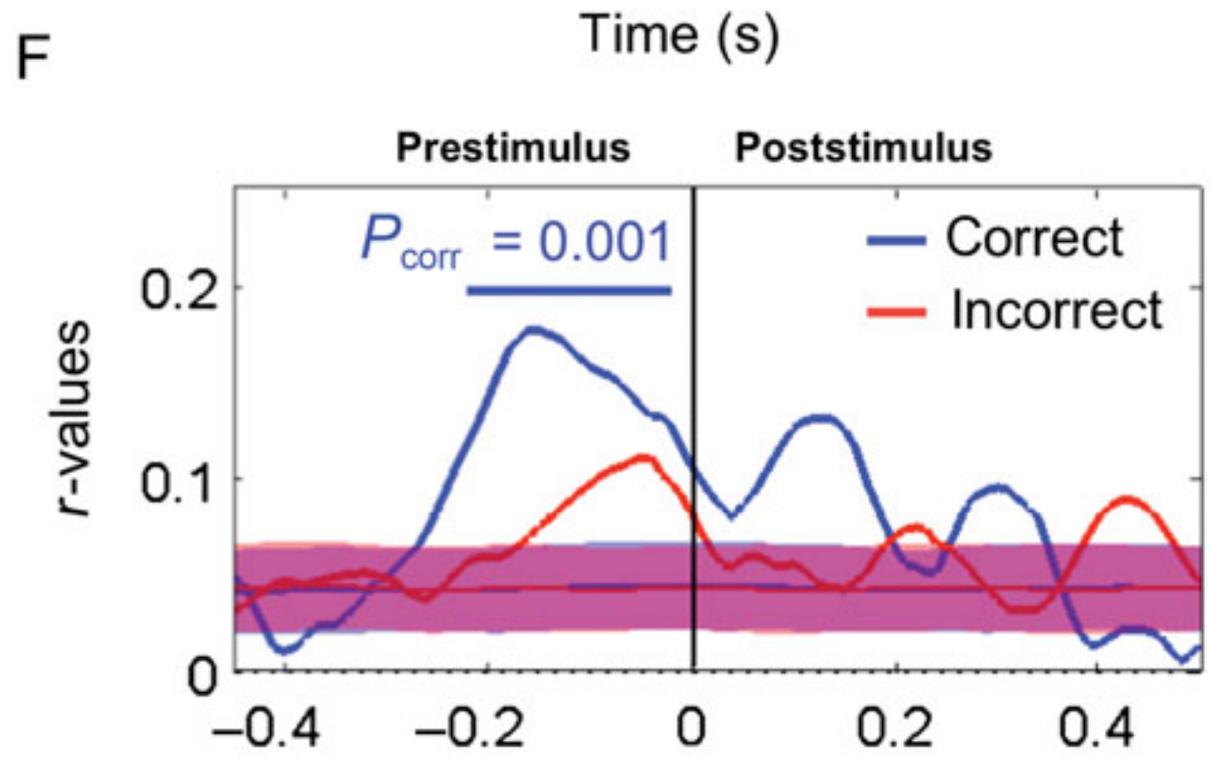
Arnal et al., 2014



Human MEG | Induced beta | Cereb. Cortex

Arnal et al., 2014





Human MEG | Induced beta | Cereb. Cortex

C. Discussion

Summary

Beta activity is strongly associated with encoding of time intervals in isochronous sequences during both passive listening, imagery and active timing tasks.

Induced beta activity decreases (desynchronization) after stimulus onset and then increases (rebound) and peaks at the time of onset of the next sound event.

Beta activity is a marker of both endogenous (top-down) as well as exogenous (bottom-up) processes underlying timing.

Sources of beta activity are widespread and include the auditory cortex as well as coupled sensorimotor networks.

Delta phase-beta amplitude coupling reflects performance in a timing task, and could used for accurate sensory selection in time.

Signatures of beta activity in isochronous sequences are disrupted in irregular sound sequences.

Open questions

Causal architecture of beta-band networks during timing - i.e. what is the source of beta activity (cf. Sherman et al., 2016 PNAS)?

What is the nature of functional connectivity between auditory and motor cortices during timing?

Why is beta activity prominent only during regular sound sequences? How robust is the beta response to temporal irregularities in the stimulus?

Are the beta sources underlying timing distinct for regular vs. irregular rhythms?

Does beta activity represent “when” or “what” information about an event?

What is the role of other oscillatory signals and their interaction with beta activity during timing?

Testable hypotheses

H_0: Induced beta activity in auditory cortex is modulated by temporal irregularity.
Use sound sequences with parametric levels of temporal jitter.

Examine whether induced beta power and delta-phase & beta-amplitude coupling are modulated parametrically as a function of the amount of temporal jitter.

H_0: Beta activity in the auditory cortex encodes maximum timing information.
Use a classifier approach to examine whether activity (beta/gamma) in auditory cortex, motor cortex, SMA, cerebellum can decode stimulus features like regularity or rate.

Classification accuracy should be higher for trained musicians vs. non-musicians.

H_0: Beta activity represents both temporal (when) and categorical (what) information.
Use a balanced factorial design with orthogonal temporal and categorical factors to examine whether induced beta activity represents when / what information.

Gracias por tu tiempo!