Behavioral induction of a high beta state leads to movement slowing

Vignesh Muralidharan and Adam R Aron
Department of Psychology, University of California, San Diego
CNS 2020 Virtual Meeting, May 5, 2020; Email: vimuralidharan@ucsd.edu

AIM and MOTIVATION

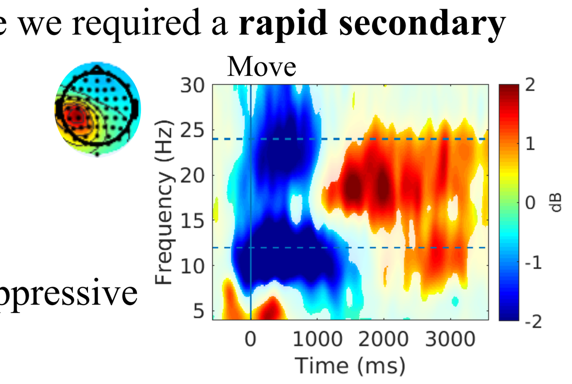
To probe the functional role of sensorimotor beta oscillations using a novel behavioral paradigm. **Beta rhythm** (~13 to 30 Hz) is a prominent electrophysiological observation over sensorimotor regions.

Better understanding the functional significance of this beta rhythm is important for both healthy functioning and disease states.

- Sorting the multiple theories of the functional significance of sensorimotor beta, requires a need for protocols in humans that manipulate/induce beta oscillations and test their putative effects on concurrent behavior.
- Straightforward behavioral route to achieve this goal.

INTRODUCTION

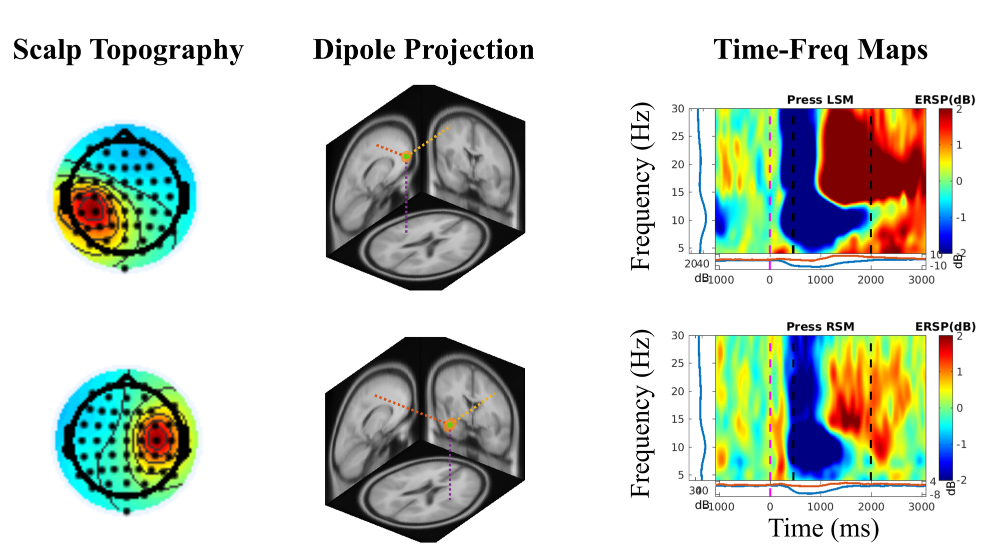
- We developed a **novel behavioral paradigm** where a participant made a primary movement, leading to a strong beta state (**post-movement beta rebound, PMBR**) in the contralateral sensorimotor cortex.
- Within the time-frame of that state we required a **rapid secondary movement**.
- Rationale for using **PMBR**
  a) Robust increase in beta power
  b) Lateralization of the rebound
  c) PMBR could be functionally suppressive



Evidence that corticospinal excitability is reduced[1] during this period and positive relationship to the GABA levels in sensorimotor regions[2].

TASK DESIGN AND METHODS

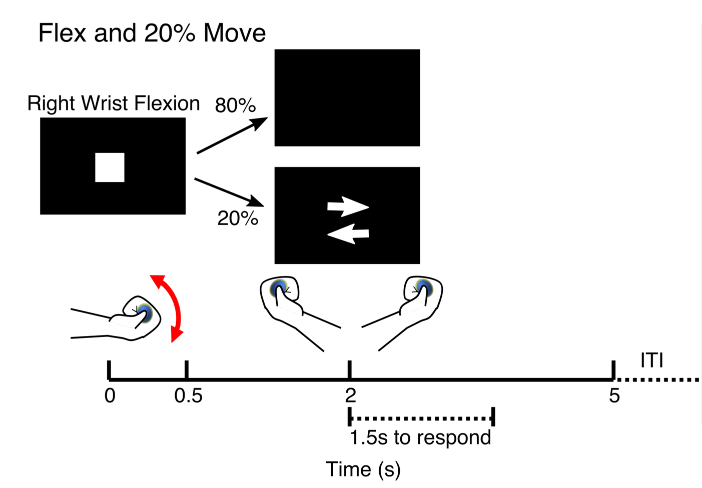
- **Two Experiments** (1 and 2): 64 channel EEG collected.
- Primary movement with the right arm followed by a secondary movement in a subset of trials (20%).
- **Expt 1**: Primary Movt – right-hand wrist Flexion, secondary movement – right/left thumb press. Recorded thumb press RTs and EMG for wrist and thumb flexors.
- **Expt 2**: Primary Movt – right-hand index finger button press, secondary movement – right/left center-out movement. Recorded RTs for primary button press and continuous joystick displacement for the secondary movements.
- EEG data was preprocessed, band-passed 2-55Hz, noisy channels were removed and other sources of noise were subtracted (including eye-blinks and muscle noise) using ASR, and noisy stretches were removed.
- To look at sensorimotor beta, we performed ICA to extract a left sensorimotor (**LSM**) and a right sensorimotor (**RSM**) IC for each subject.



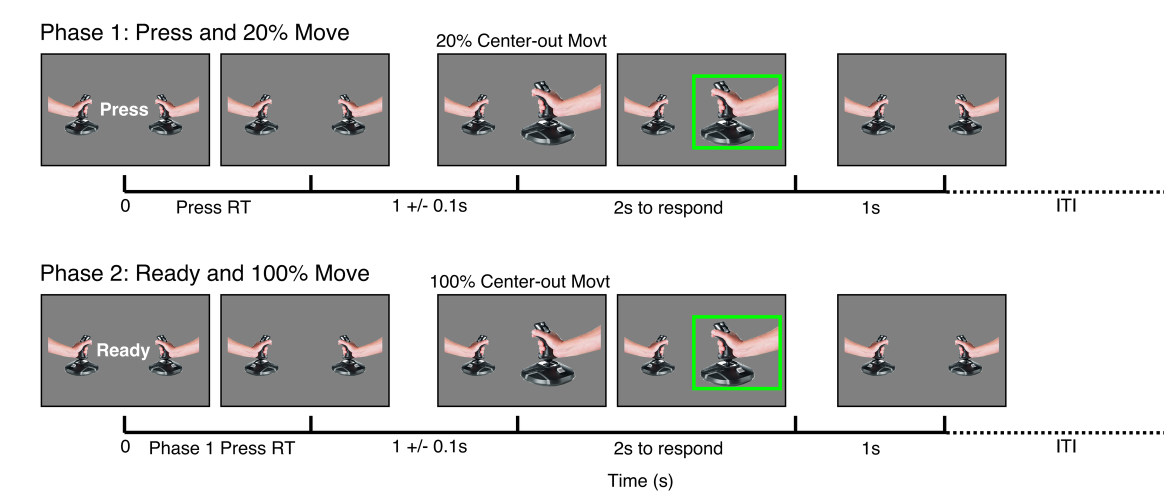
EXPERIMENT SETUP AND RESULTS

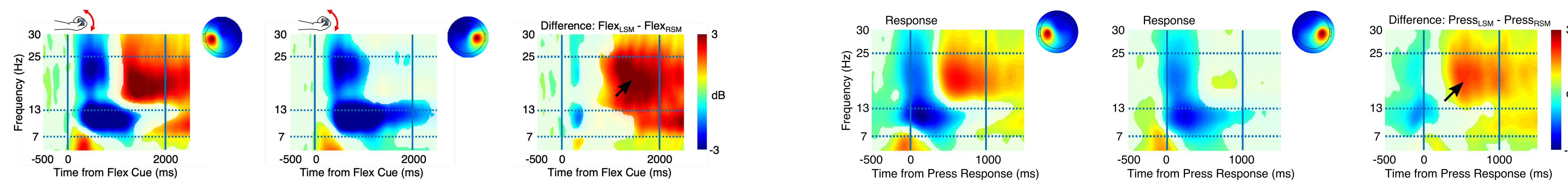
Task Setup and stronger contralateral beta rebound (LSM > RSM)

Experiment 1



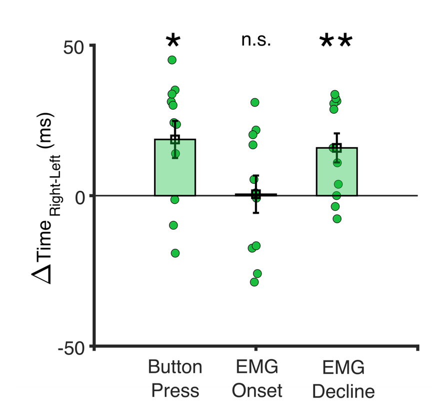
Experiment 2



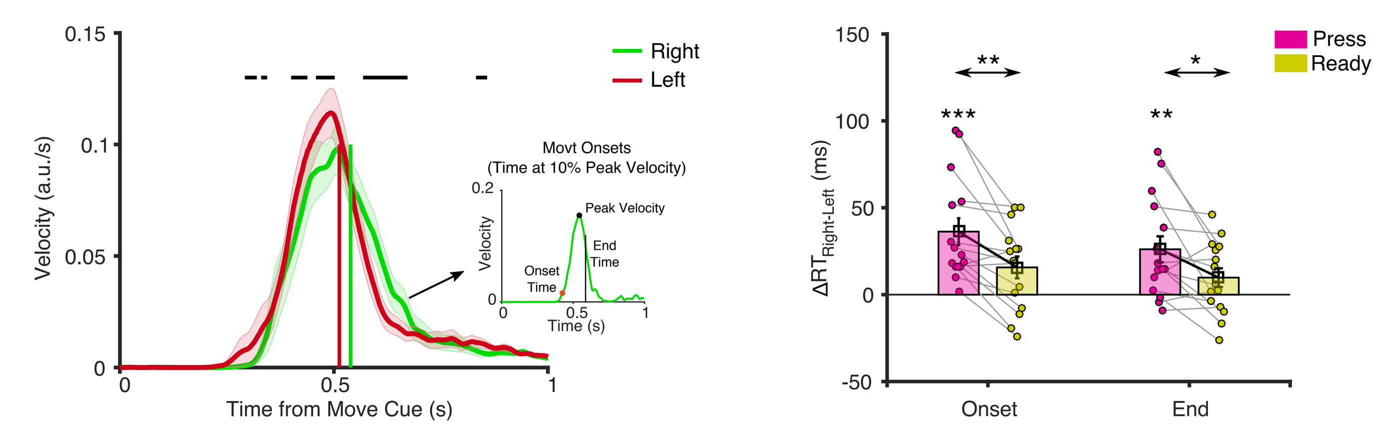


Stronger left-SM beta leads to slower subsequent secondary movement

Experiment 1: Thumb RTs and EMG

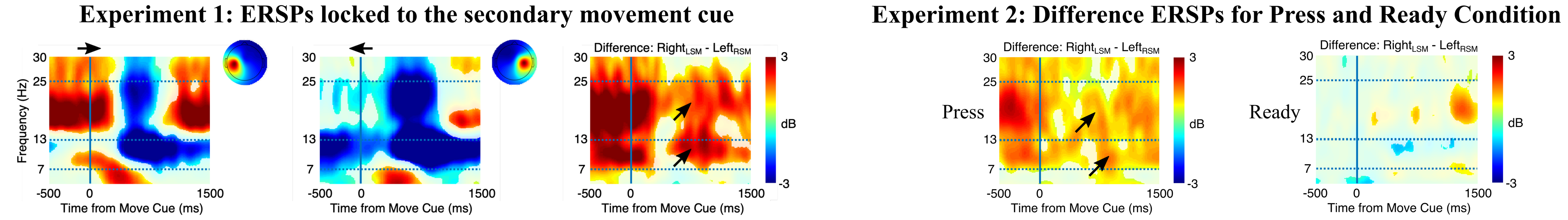


Experiment 2: Velocity profiles and movement times for the center-out movements



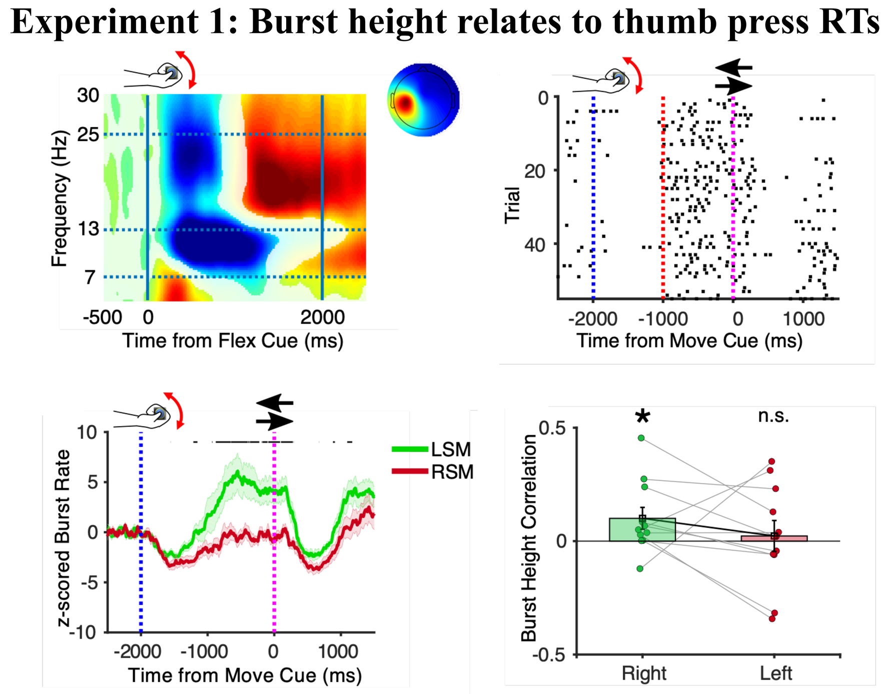
Beta rebound influences the neural signature of the secondary movement (mu/beta desync)

Experiment 1: ERSPs locked to the secondary movement cue **Experiment 2: Difference ERSPs for Press and Ready Condition**

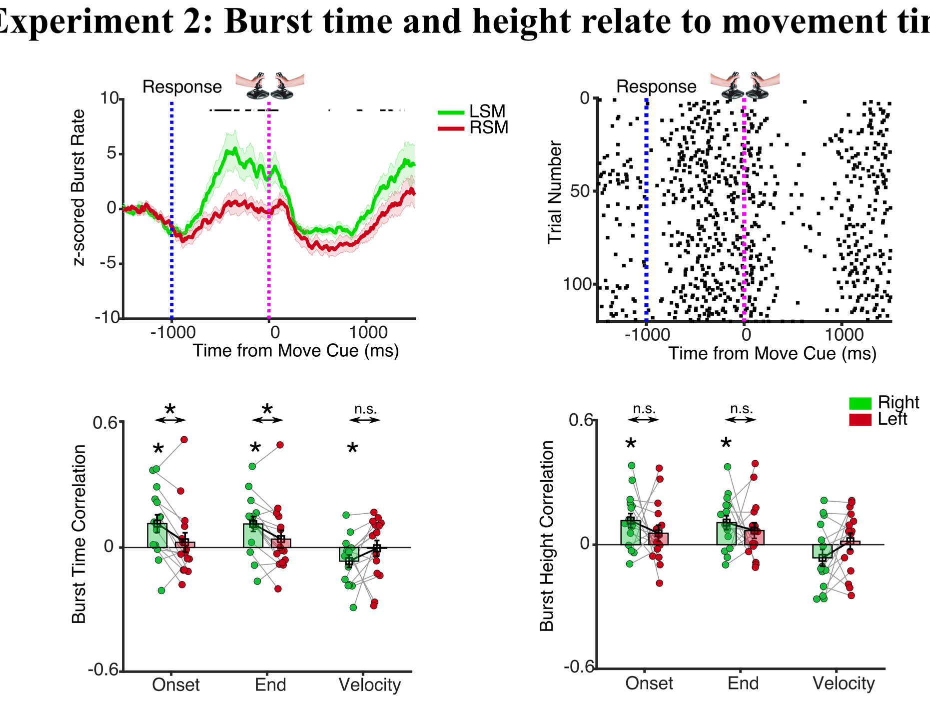


Timing and the amplitude of LSM beta bursts in the rebound period relate to the slowing

Experiment 1: Burst height relates to thumb press RTs



Experiment 2: Burst time and height relate to movement times



MAIN FINDINGS

- **PMBR slows down subsequent movement:** In both experiments we saw that the strong beta rebound over the left-SM cortex slowed down subsequent right side movement compared to the left.
- **PMBR state influences neural processing**: There was lower mu-beta desynchronization in the hemisphere preceded by a strong beta rebound, the LSM compared to the RSM.
- **Transient beta bursts related to the degree of slowing**: The timing and the the amplitude of the beta bursts just before the secondary movement cue related to the degree of movement slowing and were specific to the effector that was slowed.

DISCUSSION

- **Proactive instantiation of a retardive state**: Our study is novel because it provides an instruction to participant to voluntarily induce/create a high beta state.
- **Clinical Applications:** There are ways in which PMBR could be modulated, for e.g. the amount of force[3], briskness of movement[4]. So there might be ways to train people to better and more strongly achieve a retardive state.
- **Theoretical Implications**: Beta could be a functional "suppressive state". This fit the existing ideas of beta where it signals "status quo"[5], maintaining the current action plan, or possibly an active inhibition of the motor network[6],.
- **Limitations:** Study could have been more balanced with another condition (press left). Fatigue could still have played a role although we were able to minimize its effect in Experiment 2. We don't know how our results extend to other forms of sensorimotor beta (pre-movement beta).

FUTURE DIRECTIONS

- **Apply ideas to domains other than movement**: If PMBR indeed represents a functional suppressive state, then we could embed in there cues which test its role in sensory perception. Studies have shown increased endogenous sensorimotor beta bursts affect sensory processing[7].
- **Neurofeedback:** There could ways of achieving a strong beta state through neurofeedback. Beta rebound is also seen after imagined movements, so there might be ways to get a state which is most effective.

REFERENCES

1. Chen R, Yaseen Z, Cohen LG, Hallett M (1998) Time course of corticospinal excitability in reaction time and self-paced movements. Annals of neurology 44:317-325.
2. Gaetz W, Edgar JC, Wang D, Roberts TP (2011) Relating MEG measured motor cortical oscillations to resting γ-aminobutyric acid (GABA) concentration. Neuroimage 55:616-621.
3. Fry A, Mullinger KJ, O'Neill GC, Barratt EL, Morris PG, Bauer M, Folland JP, Brookes MJ (2016) Modulation of post-movement beta rebound by contraction force and rate of force development. Human brain mapping 37:2493-2511.
4. Stancák Jr A, Pfurtscheller G (1996) Event-related desynchronisation of central beta-rhythms during brisk and slow self-paced finger movements of dominant and nondominant hand. Cognitive Brain Research 4:171-183.
5. Engel, A. K., & Fries, P. (2010). Beta-band oscillations--signalling the status quo? *Curr Opin Neurobiol, 20*(2), 156-165.
6. Kilavik BE, Zaepffel M, Brovelli A, MacKay WA, Riehle A (2013) The ups and downs of beta oscillations in sensorimotor cortex. Experimental neurology 245:15-26.
7. Shin H, Law R, Tsutsui S, Moore CI, Jones SR (2017) The rate of transient beta frequency events predicts behavior across tasks and species. Elife 6:e29086.

Funding: NIH DA026452 and the James S McDonnell Foundation 220020375