Dissociating Proactive and Reactive Conflict in the Subthalamic Nucleus

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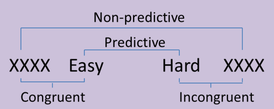
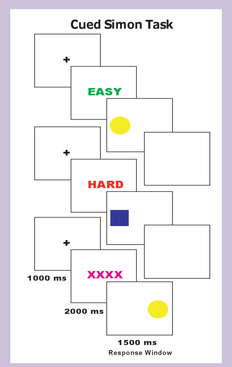
Abstract

- The subthalamic nucleus (STN) contributes to adaptive control by temporarily preventing response execution, buying time for the best response to be selected.[1]
- This suggests two separable functions of the STN: increased activity to cues signaling potentially conflicting outcomes, and increased activity during motor response conflict.
- It was predicted that these specific functions would be revealed when: 1) a cue indicates slowing or inhibition is needed and 2) when actions compete for execution.
- Greater STN activity to both 1) proactive signals of upcoming conflict and 2) reactive signals of stimulus-response conflict was observed.
- These findings implicate the role of the STN in both cognitive and motor conflict, and identify a potential mechanism for conflict-instantiated cognitive control.

Methods

N = 6; Parkinson's patients undergoing DBS surgery; iEEG recorded from left STN; 4 depth electrodes, bipolar referenced.



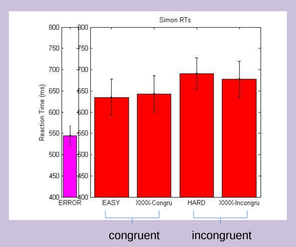


Cross-over design yields the following contrasts:
1) Proactive Conflict:
 - non-predictive minus predictive (informative cues)
 - preparatory conflict without stim-response conflict
2) Reactive Conflict:
 - incongruent minus congruent
 - imperative cues (i.e. yellow circle) and responses
 - stimulus-response conflict

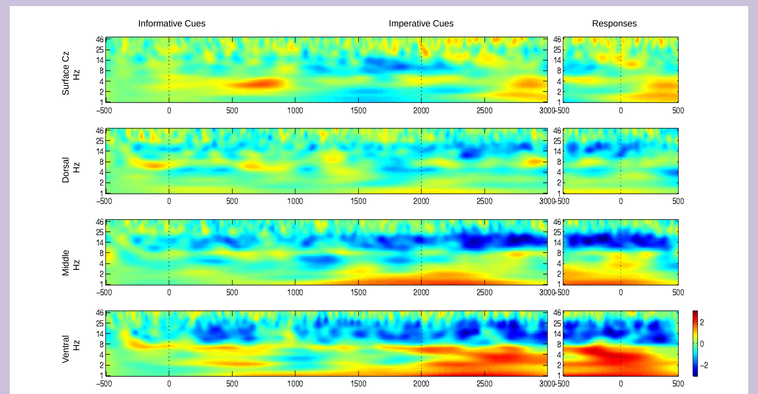
Patients were off Parkinson's medication for 24 hours, although some had surgery-specific medications.

Behavioral results indicate that patients took longer on trials that involve response conflict.

Control subjects perform similarly on this task[2]

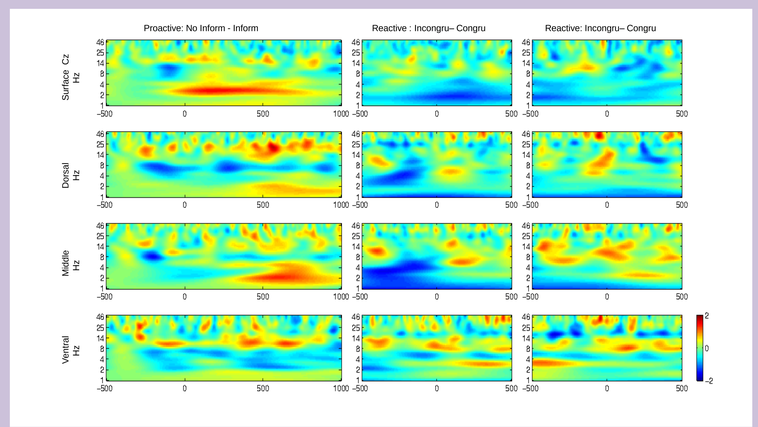


Time-Frequency Power Collapsed Across Conditions



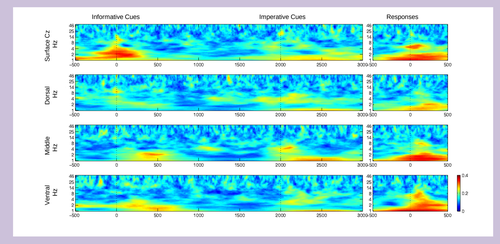
- Delta/theta increases for informative and imperative cues and responses at depth electrodes and Cz, replicating previous findings.[1]
- Beta suppression found throughout.

Condition Differences in Time-Frequency Power



- Informative Cues (Proactive signals) : Delta/theta increases in dorsal and middle electrode and high frequency (alpha/beta) increases in all depth electrodes; delta/theta increases at Cz.
- Imperative Cues (Reactive signals): Theta increases at middle and dorsal electrodes, delta increases at ventral electrodes.
- Response (Reactive signals): Delta/theta increases at middle electrode; alpha increases at ventral electrode.

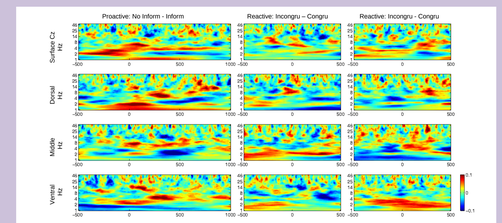
Inter-Trial Phase Coherence Collapsed Across Conditions



- Low-frequency increases in phase coherence across conditions.

Condition Differences in Phase Coherence

- Increases in phase coherence relate to increases in power.



Discussion

- The mPFC is thought to facilitate deliberate control over behavior, in part via a "hyperdirect" pathway with the STN. [2,3]
- Differential activity in the STN was observed for proactive conflict and reactive conflict.

  An increase in low frequency activity in the STN was observed when a cue indicated inhibition or slowing was needed. This provides evidence for a proactive role for the STN in behavioral control.

  Increased activity in the theta range for imperative cues, and in the low frequency during responses, replicated previous findings of reactive control due to response conflict in the STN.[4]
- This finding provides evidence for a neural network by which mPFC-registered conflict can implement cognitive control by raising the response threshold for basal ganglia output via the STN.
- These findings support the notion that the mPFC-STN conflict-control system may be instantiated via communication in low frequency bands. [4]

References

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[3] Aron, A.R., Behrens, T.E., Smith, S., Frank, M.J. & Poldrack, R.A. (2007). Journal of Neuroscience.
[4] Cavanagh, J.F., Wiecki, T.V., Cohen, M.X, Figueroa, C.M., Samanta, J., Sherman S.J., & Frank, M.J. (in press). Nature Neuroscience

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