Figures and figure supplements

Non-selective inhibition of inappropriate motor-tendencies during response-conflict by a fronto-subthalamic mechanism

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Figure 1. Task diagrams for all experiments. (A) Visual Simon task. Fixation was followed by a colored square, with color indicating the required response hand (according to the response mappings, which were displayed on the bottom of the screen throughout the experiment). Response hand either matched the side of stimulus presentation (congruent trial) or did not match (incongruent trial). Incongruent trials introduced response-conflict. In Experiment 1 (EEG), responses were made with the hands, whereas in Experiment 3.1. and 3.2. (TMS and EMG) they were made with the feet so that the hand muscles were task-unrelated. (B) Visual stop-signal task used in Experiment 1 to evoke neural signature of motor inhibition. (C) Auditory Simon task, used in Experiment 2. Intraoperative recordings were performed on participants with partially occluded vision, therefore the experiment was conducted entirely in the auditory domain. A high-frequency tone indicated a right hand response, a low frequency tone indicated a left hand response. Response-conflict was created through incongruent laterality of the stimulus presentation, same as in the visual experiment used in Experiments 1, 3.1., and 3.2.

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Figure 2. Results from Experiment 1. (A) Group-average event-related potential and event-related spectral perturbation of the selected independent EEG source-signal components during the stop-signal task. The left panel shows the event-related stop-signal P3 activity of these components, while the right panel shows that the bulk of the signal increase of these components during successful stopping is found between 2 and 8 Hz. (B) Relationship between the onset of the event-related part of the components in panel A to behavioral measures of motor inhibition in the stop-signal task. The onset of the stop-signal P3 occurred significantly earlier in successful vs. failed stop-trials (left panel). Moreover, the latency of P3 onset was positively correlated with the speed of stopping across subjects (right panel). (C) Activity of these same components during response-conflict in the Simon task. The left panel shows a significant (p<0.01, FDR-corrected) increase in low-frequency activity on incongruent vs. congruent trials on the group-level. The right panel shows the results of a trial-by-trial correlation between the degree of motor slowing on each individual incongruent trial and the activity of the selected components, revealing a positive relationship between the same low-frequency activity and motor slowing during response-conflict. (D) Illustration of that same relationship on individual trials, stacked across all subjects (for visualization purposes only). Y-Axis shows individual incongruent trials, sorted by reaction time (curved black line). Stronger low-frequency activity can be observed on trials with more motor slowing (top of graph). DOI: https://doi.org/10.7554/eLife.42959.003
Figure 3. Confirmation of STN electrode placement. Bipolar STN electrode montages from selected electrodes show power peaks in $\beta$-band for each individual subject; red line shows average across all subjects (red shade: standard error of the mean).

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Figure 4. Confirmation of subgaleal M1 electrode placement. Top row: Bipolar subgaleal electrode contact montages over M1 show clear motor signatures; β-desynchronization over contralateral M1 on congruent trials can be observed in both left M1 (left) and right M1 (middle). Furthermore, single-trial data show clear alignment of this desynchronization to the response, followed by post-response β-rebound (right). Middle and bottom row: β-desynchronization is localized to the selected montages, as signatures are largely reduced/absent at anterior/posterior montages.
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Figure 5. STN – M1 functional and effective connectivity during conflict. (A) Functional connectivity, phase-locking value. Left panel shows the full-spectrum PLV analysis, specifically, a comparison of incongruent minus congruent trials. Significant (p<0.01) group-differences between conditions are highlighted in black outline. To visualize the condition differences in the significant frequency-range, the middle panel shows individual condition data in the significant beta frequency-range, which was identified from the full spectrum analysis (18–22 Hz). Right panel shows individual subject condition differences (positive numbers indicate greater PLV in the incongruent condition). (B) Effective connectivity (Granger prediction). Top row shows directional influence of STN activity onto ipsilateral M1, bottom row shows the reverse direction. Left panels show full beta-spectrum analysis, significant (p<0.01) increases in directional connectivity (from baseline) are highlighted in black. Middle panels show the effective connectivity time-series at the significant frequencies identified for STN→M1 connectivity from the full-spectrum analysis. Right panels show individual subject data for the significant time-frequency window.

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Figure 5—figure supplement 1. STN – contralateral M1 connectivity during conflict. Top row: PLV analysis for contralateral M1-STN functional connectivity. Details are the same as Figure 5A. Bottom row: Bayes factor analysis used to quantify evidence for the null hypothesis for the data depicted in the top row. Left: full-spectrum Bayes factor quantifying evidence for the null hypothesis (H0); right: evidence for null and alternative hypothesis (H1) for the frequencies that yielded the strongest connectivity in Figure 5.

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Figure 6. Results from Experiment 3.1. (left) and Experiment 3.2. (right). Experiment 3.1. showed significant suppression of CSE on incongruent-trials at 250 ms post-stimulus. Experiment 3.2. replicated this finding in a larger sample, and also showed that incongruent-trial CSE was significantly suppressed compared to resting baseline. Lastly, the degree of MEP suppression incurred on incongruent trials was positively correlated with the amount of relative RT slowing on those trials.

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