Supplementary Materials

Evoked midfrontal activity predicts cognitive dysfunction in Parkinson’s disease

Supplementary Methods

**Apparatus:** All participants sat in a quiet room in front of a computer for behavioral assays during EEG recordings. All task stimuli were presented via the PsychToolbox-3 functions\(^1,2,3\) in MATLAB on a Dell XPS workstation with a 19-inch monitor. Task-specific audio was played through Dell Rev A01 speakers positioned on either side of the monitor, and responses were made with the left and right index fingers on a standard QWERTY USB-keyboard. All participants performed the Simon task, oddball task, and interval timing task. Each of these paradigms have been extensively studied from the perspective of cognitive control and PD, and were specifically selected to study cognitive control in PD.\(^4-9\)

**Oddball task:** The appearance of the arrow was preceded by an audio-visual cue by 0.5 seconds (either the standard cue or the distractor cue). Participants were instructed that this cue would appear 0.5 seconds before the target stimulus (white arrow), and that this cue would be a green circle and a short tone (600-Hz sine wave tone lasting 0.2 seconds). The audio-visual cue was followed by the target arrow (Figure 1B). Participants had to respond within 1 s, after which the fixation cross reappeared and the next trial started after a variable inter-trial interval between 0.5 – 1 second. Participants completed a brief practice of the task (10 trials), which had all the familiar standard cues described above.
**Interval-timing task:** White instructional text on the center of a black screen was presented that read “Short interval” on 3-second interval trials and “Long interval” on 7-second interval trials. The actual interval durations were never communicated to the patient; we only analyzed long interval trials in this manuscript because our previous study observed no significant differences between PD and control subjects during short interval trials.\(^6,^{10}\) Participants were instructed not to count, and a distractor vowel appeared at random intervals in the screen center. Participants took a self-paced break between each block and moved to the next block by pressing any key.

**EEG Recordings**

Briefly, we used a 64-channel EEG actiCAP (Brain Products GmbH) with a 0.1-Hz high-pass filter and a sampling frequency of 500 Hz. We used electrode Pz as an online reference and electrode site Fpz for the ground. EEG activity was referenced according to the procedures described in Singh et al.\(^7,^{11}\) An additional channel was recorded at the mid-inion region (Iz), and we removed unreliable FT9, FT10, TP9, and TP10 channels, resulting in 59 channels for pre- and post-processing. Data were epoched around the cues from -1 to 2.5 seconds peri-cue.
**Supplementary References**


Supplementary Figures

Figure S1: Control-related slowing on Simon and oddball tasks. Top: differences in response latencies (in seconds) on incongruent vs. congruent trials for control (gray), PD patients (red), PDMCI (orange), and PDD (plum) from the Simon task. Bottom: differences in response latencies (in seconds) on oddball vs. standard trials for control (gray), PD patients (red), PDMCI (orange), and PDD (plum) from the oddball task. Black bar is the median across participants. Data from the same patients as in Figure 1.
Figure S2: Event-related potential components are not reliably affected by cognitive dysfunction in PD: ERP voltage during the Simon task from electrode Cz for A) congruent and B) incongruent trials for response times for congruent and incongruent trials for 48 control (gray), 47 PD (red), 34 PDMCI (orange), and 18 PDD (plum) patients; the black bar is the median. C) Average amplitudes across patients; the black bar is the median. ERP voltage during the oddball task from electrode Cz for D) standard and E) oddball trials for 41 control, 44 PD, 29 PDMCI, and 17 PDD patients. F) Average amplitudes across patients; the black bar is the median; *main effect of trial type; # main effect of group. G) ERP voltage during the interval timing task from electrode Cz for 41 control, 43 PD, 31 PDMCI, and 18 PDD patients. H) Average amplitudes across patients; the black bar is the median. Note that ERPs are plotted with negative voltages up.
Figure S3: Oddball ERPs. A) ERP voltage during the oddball task from electrode Cz for standard and B) oddball trials C) Average amplitudes from 0.05 – 0.15 seconds across patients. The black bar is the median. Data from the same patients as in Figure S2.
Figure S4: Cue-triggered midfrontal beta rhythms as a function of cognitive dysfunction in PD. PD-related cognitive function did not affect beta power for beta bands from electrode Cz for the Simon task (ROI: 13-30 Hz; 0.2-0.55 seconds), the oddball task (ROI: 13-30 Hz; 0.2-1.0 seconds; there was a main effect of group due to increased beta power in all PD groups: F=4.5, p=0.01); and interval timing (ROI: 13-30 Hz; 0.2-0.9 seconds). The black bar is the median. Data from the same patients as in Figure 3.
**Figure S5: Control-related power.** Power from electrode Cz corresponding to ROIs in Figure 3 during the Simon task on incongruent - congruent trials (left), and during the oddball task on oddball – standard trials (right). The black bar is the median. Data from the same patients as in Figure 3.
**Figure S6:** PC1 correlations with MOCA and NIH Toolbox Executive Function for 35 control participants. Neither relationship was reliable.