Table S1: Demographic summary for 17 PD STN DBS patients who completed the MSIT, split into subgroups based on MOCA score.

		All (N=17)	PD (N=7)	PDCI (N=10)
	Age (in years)	69.4 ± 1.6	69.3 ± 1.7	69.4 ± 2.5
	Sex (female %)	24%	29%	20%
	Education	16 ± 1	17 ± 2	16 ± 1
	MOCA	23.7 ± 0.9	26.4 ± 0.2	21.8 ± 1.1
	Disease Duration	10. ± 1.1	9.6 ± 1.3	10.4 ± 1.7
MDS-UPDRS Part III	**STN DBS OFF**	43 ± 5	27 ± 7	55 ± 4
	STN DBS 4 Hz	34 ± 4	24 ± 5	41 ± 6
	STN DBS~130 Hz	24 ± 3	15 ± 6	29 ± 3
	LEDD	1087 ± 182	1386 ± 359	877 ± 168

PD: Parkinson's Disease; PDCI: Parkison's Disease - Cognitive Impairment; CA: Montreal Cognitive Assessment; MDS-UPDRS: Movement Disorders Society Unified Parkinson's Disease Rating Scale; LEDD: Levodopa equivalent daily dose

Table S2: Demographic summary for 10 PDCI patients who completed the MSIT

		PDMCI (N=6)	PDD (N=4)
	Age (in years)	69.9 ± 2.6	68.7 ± 5.3
	Sex (female %)	33%	0%
	Education	16.5 ± 1.7	14.2 ± 1.0
	MOCA	24.3 ± 0.3	18.0 ± .8
	Disease Duration	10.4 ± 2.6	10.5 ± 2.1
MDS-UPDRS Part III	**STN DBS OFF**	56.0 ± 5.7	52.2 ± 6.8
	STN DBS 4 Hz	37.5 ± 8.1	47.0 ± 8.4
	STN DBS~130 Hz	29.2 ± 5.0	28.5 ± 3.5
	LEDD	1066.7 ± 206.1	593.5 ± 24

PD: Parkinson's Disease; PDCI: Parkison's Disease - Cognitive Impairment; PDMCI: Parkinson's Disease Mild Cognitive Impairment; PDD: Parkinson's Disease Dementia; MOCA: Montreal Cognitive Assessment; MDS-UPDRS: Movement Disorders Society Unified Parkinson's Disease Rating Scale; LEDD: Levodopa equivalent daily dose

Table S3: Levodopa and DBS programming characteristics. Thick border delineates MOCA-based subgroups (mild cognitive impairment (PDMCI) = MOCA 22-25; PD dementia (PDD) = MOCA <22).

Group	LEDD	MOCA	Right STN		Left STN		UPDRS		
							OFF	4 Hz	~130 Hz
PD	550	27	130Hz	11+ 10- 0.5V 60µs	130Hz	C+ 3- 0.5V 60µs	9	14	3
PD	1243	27	125 Hz	9+ 11- 1.95V 60 µs	125 Hz	3+ 2- 1.4V 60µs	25	20	9
PD	3150	27	160 Hz	C- 10- 2.2V 90 µs	160 Hz	3+ 2- 2.4V 90µs	15	7	11
PD	2079	26	140 Hz	10- 9+ 1.9V 90 µs	140 Hz	C+ 2- 0.75V 60µs	41	37	9
PD	600	26	120 Hz	11+ 10- 4V 60 µs	120 Hz	3 + 1- 3.4V 70µs	59	40	42
PD	1380	26	130 Hz	C+ 9- 60 µs	130 Hz	C+ 2- 1.1mA 60µs	23	31	29
PD	700	26	130 Hz	11+ 9- 3.4V 90 µs	130 Hz	3+ 1- 3.2V 70µs	18	22	5
PDCI	900	25	130 Hz	11 + 10- 1.6V 60 µs	130 Hz	3+ 2- 2.15V 60µs	36	9	13
PDCI	1285	25	110 Hz	3 + 2- 4.35V 100 µs	110 Hz	3+ 2- 4.25V 150µs	76	60	32
PDCI	650	25	130 Hz	C+ 10-/9- 3.3V 90 µs	130 Hz	C+ 2- 3.2V 90µs	45	21	19
PDCI	1980	24	80 Hz	11+ 10- 1- 3.45V 60 µs	80 Hz	3+ 2-/1- 3.45V 90µs	61	57	45
PDCI	650	24	130 Hz	C+ 9- 1.7V 60µs	130 Hz	C+ 1- 1.4V 60µs	56	38	28
PDCI	935	23	130 Hz	C+ 11- 2V 60 µs	130 Hz	C+ 3- 2V 60µs	62	40	40
PDCI	374	20	130 Hz	C+ 10- 1.5V 90µs	130 Hz	3+ 1-/ 2- 5.6V 90µs	63	62	31
PDCI	950	18	130 Hz	3+ 1- 1.0V 60 µs	130 Hz	11- 10+ 1.0V 60µs	33	23	18
PDCI	1050	18	150 Hz	C+ 8- 3.8V 90 µs	150 Hz	C+ 3- 3.5V 80µs	53	49	32
PDCI	0	16	140 Hz	11+/10+ 9- 3.9V 110 µs	140 Hz	3+ 2-/1- 3.9V 110µs	60	54	33

LEDD, Levodopa-equivalent dose; MOCA, Montreal Cognitive Assessment; STN, subthalamic nucleus; UPDRS, Unified Parkinson's Disease Rating Scale, Part III total score; PD, Parkinson's Disease; PDCI, Parkinson's Disease- Cognitive Impairment

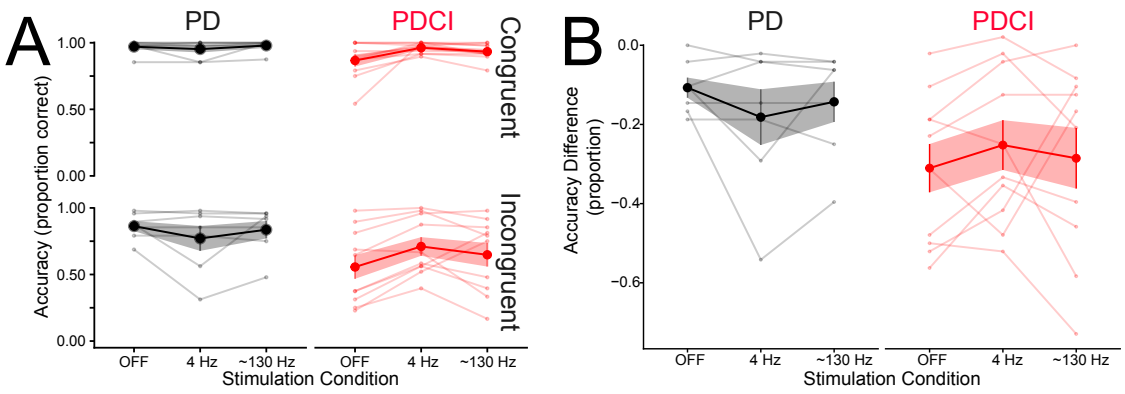
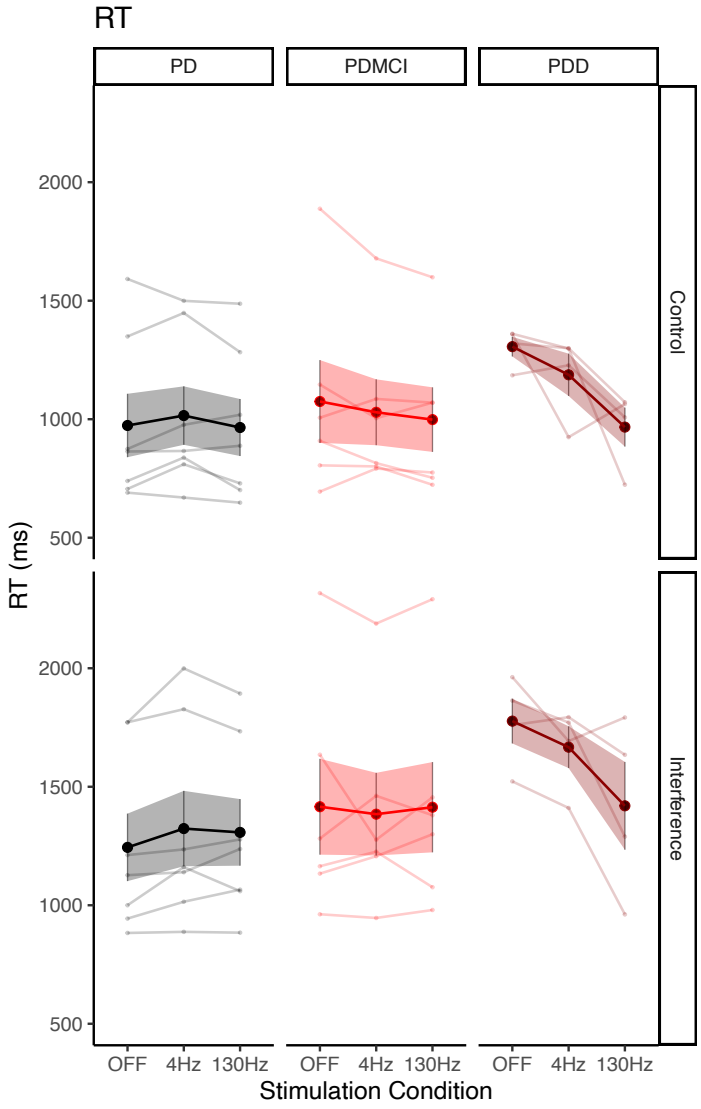


Figure S1: Accuracy in patients with PD and PD Cognitive Impairment (PDCI). A) Multi-Source Interference Task (MSIT) accuracy for patients with Parkinson's Disease (PD) with a MOCA ≥ 26 (grey; PD) or < 26 (red; PDCI) under stimulation conditions STN DBS OFF, 4 Hz, and ~130 Hz for congruent and incongruent trials. **B**) Accuracy interference cost. Data are from 4896 trials of the MSIT performed by 7 patients with PD without cognitive impairment (grey) and 10 patients with PDCI (red); thin lines represent mean data from a single patient; thick lines represent mean across patients, and shaded area represents standard error of the mean.

Figure S2: Subthalamic Nucleus (STN) Deep Brain Stimulation (DBS) at 4 Hz speeds reaction times in patients with PD Cognitive Impairment (PDCI). A) Multi-Source Interference Task (MSIT) reaction time for patients with Parkinson's Disease (PD) with a MOCA ≥ 26 (grey; PD) MOCA 22-25 (red; PDMCI) or MOCA ≤ 22 (dark red, PDD) under stimulation conditions STN DBS OFF, 4 Hz, and ~130 Hz. Data are from 4896 trials of the MSIT performed by 7 patients with PD without cognitive impairment (grey), 6 patients with PDMCI (red) and 4 patients with PDD (dark red); thin lines represent mean data from a single patient; thick lines represent mean across patients, and shaded area represents standard error of the mean.



CONSORT Checklist

Section/Item	**Item No.**	**Checklist Item Descriptor**	**Reported in Manuscript (Section, Page, or Line #)**
Abstract	1b	Structured summary of trial design, methods, results, and conclusions.	Abstract
Background	2a	Scientific background and explanation of rationale.	Introduction
Objectives	2b	Specific objectives or hypotheses.	Introduction
METHODS			
Trial Design	3a	Description of trial design (e.g., parallel, crossover) including allocation ratio.	Methods: Detailed as a within-subject, counterbalanced Latin squares crossover design across 3 arms.
Changes to Design	3b	Important changes to methods after trial commencement.	Methods: Explicitly accounts for 20 patients enrolled but only 17 completing all three arms.
Participants	4a	Eligibility criteria for participants.	Methods: Details criteria (PD with bilateral STN DBS >= 6 months on stable settings).
Settings	4b	Settings and locations where the data were collected.	Methods: Movement disorders clinics at the University of Iowa.
Interventions	5	The interventions for each group with sufficient details to allow replication.	Methods: Outlines 4 Hz DBS parameters, clinical settings (~130 Hz), OFF state, washout period (20 mins), and MSIT task architecture.
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures.	Methods: Explicitly states reaction times and accuracy as key behavioral outcomes; motor performance via MDS-UPDRS III.
Changes to Outcomes	6b	Any changes to trial outcomes after the trial started.	None reported.

Sample Size	7a	How sample size was determined.	Convened clinical sample cohort (N=20 enrolled, N=17 analyzed).
Interim Analyses	7b	When applicable, explanation of any interim analyses.	Not applicable.
ASSIGNMENT & SEQUENCE			
Sequence Generation	8a	Method used to generate the random allocation sequence.	Methods: Standard Latin squares design configuration.
Sequence Detail	8b	Type of restriction (e.g., blocking, counterbalancing).	Methods: Counterbalanced order of stimulation conditions explicitly stated (~130Hz -> 4Hz -> OFF)
Allocation Concealment	9	Mechanism used to implement the allocation sequence.	Unblinded clinical adjustments managed by a movement disorders neurologist.
Implementation	10	Who generated the allocation sequence, who enrolled participants, and who assigned participants.	Methods: Enrolled via UI clinics; adjustments administered by N.N., C.G., or Q.Z.
Blinding	11a	If done, who was blinded after assignment to interventions.	Open-label behavioral crossover; adjustments dictated by clinical necessity.
Blinding Similarity	11b	If relevant, description of the similarity of interventions.	Not applicable.
Statistical Methods	12a	Statistical methods used to compare groups for primary and secondary outcomes.	Methods: Linear mixed-effects models (lmer) for log reaction times; generalized mixed-effects logistic regression (glmer) for binomial accuracy.
Additional Methods	12b	Methods for additional analyses, such as subgroup analyses.	Methods: Subgroup evaluations utilizing MoCA criteria to segment into PD vs. PDCI.

Crossover Specifics	12c	Statistical methods accounting for the crossover design (e.g., period/carryover effects).	Results: Explicitly states testing for carryover/fatigue by modeling trial number within sessions and order of stimulation condition on reaction time, proving no significant effect.
RESULTS			
Participant Flow	13a	Flow of participants through each stage (diagram strongly recommended).	Methods/Results: N=20 enrolled -> N=17 completed all 3 sequence arms and included in final analysis.
Losses/Exclusions	13b	Losses and exclusions after randomization, with reasons.	Methods section: Excluded 3 subjects due to inability to complete all three required arms of the crossover paradigm.
Recruitment	14a	Dates defining the periods of recruitment and follow-up.	Retrospective sample presentation.
Trial Cessation	14b	Why the trial ended or was stopped.	Completed protocol enrollment targets.
Baseline Data	15	A table showing baseline demographic and clinical characteristics for each group.	Table 1 / Table S1: Provides full summary of Age, Sex, Education, MoCA, Disease Duration, and LEDD baseline values.
Numbers Analyzed	16	For each primary/secondary outcome, number of participants (denominator) included in each analysis.	Results section: N=17 patients analyzed over a total tracking footprint of 4,037 validated trials.
Outcomes & Estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision.	Results section: Comprehensive reporting of F-statistics, Chi-square tests, p-values, and Odds Ratios for reaction times, accuracy metrics, and UPDRS III.

Binary Outcomes	17b	For binary outcomes, presentation of both absolute and relative effect sizes.	Results section: Accuracy odds ratios presented for both PDCI (OR=0.3 vs OFF; 1.6 vs 130 Hz) and PD groups.
Ancillary Analyses	18	Results of any other analyses performed, including subgroup analyses.	Results section: Outlines continuous regression alternative treating MoCA scores as a non-binarized continuous metric.
Harms	19	All important harms or unintended effects in each group.	Methods section: Actively monitored intra-session by a movement disorders neurologist.
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and multiplicity.	Discussion
Generalizability	21	Generalizability (external validity, applicability) of the trial findings.	Discussion
Interpretation	22	Interpretation consistent with results, balancing benefits and harms.	Discussion
OTHER INFORMATION			
Registration	23	Registration number and name of trial registry.	Institutional review board approval provided (IRB # 201707828).
Protocol	24	Where the full trial protocol can be accessed, if available.	Managed under standard University of Iowa institutional protocol guidelines.
Funding	25	Sources of funding and other support, role of funders.	Funded via NINDS, Fraternal Order of Eagles Neurodegeneration Fund, and Athens Fund.