

Auditory Single-Unit Responses in the STN Provide Sensorimotor Context for Speech

WSSFN 2025 Interim Meeting. Abstract 0030

Alan Bush, Yanming Zhu, Price Latane Bullock, Matteo Vissani, Robert Mark Richardson.
Massachusetts General Hospital. Boston. USA

Corresponding author: Alan Bush, email: alan.bush@mgh.harvard.edu

How to Cite: Bush A, Zhu Y, Latane Bullock P, Vissani M, Mark Richardson R. Auditory Single-Unit Responses in the STN Provide Sensorimotor Context for Speech: WSSFN 2025 Interim Meeting. Abstract 0030. NeuroTarget [Internet]. 2025;19(2):14.

Abstract

Introduction: The basal ganglia (BG) have traditionally been implicated in movement initiation, selection, and termination,¹ yet their contribution to speech motor control remains under-explored.² Recent intraoperative recordings from our group and others demonstrate articulator-specific activation of the subthalamic nucleus (STN) during speech production.³⁻⁵

Furthermore, our recent work analyzing cortical evoked potential following STN stimulation suggests monosynaptic projections from the superior temporal gyrus (STG) to the STN,⁶ possibly via the hyperdirect pathway.⁷

We hypothesized that STN single units track auditory cues, providing a sensorimotor context relevant to speech.

Method: We conducted intraoperative recordings in Parkinson's disease (PD) patients undergoing awake DBS surgery. Two cohorts were studied: Cohort 1 (n = 25, 21M/4F, age 65.4±7.1y, IRB #20070368), from 2017–2019 at The University of Pittsburgh (Pitt); Cohort 2 (n = 23, 17M/6F, age 63±9y, IRB #2019P003841), from 2020–2024 at MGH. Microelectrode recordings (MER) captured STN single-unit activity during an auditory cue presentation and speech production tasks. Sorted units (Plexon) were required to meet well-defined stability and isolation criteria. Instantaneous firing rates (FR) were analyzed in 50ms windows, and significant deviations from baseline were detected (permutation test, p < 0.05, FDR corrected).

Results: In Cohort 1, participants performed a consonant-vowel (CV) syllable triplet repetition task. As previously reported,⁴ STN units modulated their FR during speech production. Interestingly, we identified STN neurons whose FR were modulated by the auditory presentation of the CV syllables. A subset of these auditory-responsive units exhibited phoneme and sequence specificity; notably, all these auditory-feature-encoding units were activated during overt speech. In a second task (Cohort 2), subjects read aloud sentences in either a QUIET condition or in cocktail-party NOISE to elicit the Lombard effect (i.e., an involuntary increase in speech volume with background noise). We replicated in this data our findings of speech-related STN modulation. However, although the Lombard effect was robustly elicited,

units that modulated their FR during speech did not show increased activity in the NOISE condition. Interestingly, we discovered an independent population of units whose FR scaled with background noise level.

Discussion: These data position the STN as a site of integration of acoustic information into BG loops governing speech motor control. The fact that only production-active neurons encode phonemic and sequence details during listening suggests these units carry sensorimotor information relevant for fluent articulation. Noise-sensitive units may underlie automatic adjustments in vocal effort (Lombard effect). Given that DBS often enhances speech volume yet impairs articulation precision and intelligibility, we propose a model in which BG output modulates articulatory gain, prosody, and volume based on sensorimotor context.

Conclusions: The STN is a key BG input nucleus whose neurons encode acoustic information regarding phones, sequence, and background noise. These auditory single-unit responses suggest the STN provides essential sensorimotor context for speech motor control.

References

1. Bergman H. The Hidden Life of the Basal Ganglia. (MIT Press, Cambridge, Massachusetts, 2021).
2. Manes JL. et al. A neurocomputational view of the effects of Parkinson's disease on speech production. *Front. Hum. Neurosci.* 2024;18:1383714
3. Chrabaszcz A, et al. Subthalamic Nucleus and Sensorimotor Cortex Activity During Speech Production. *J Neurosci.* 2019;39:2698–2708
4. Lipski WJ, et al. Subthalamic nucleus neurons encode syllable sequence and phonetic characteristics during speech. *J. Neurophysiol.* 2024;132:1382–1394
5. Tankus A. & Fried I. Degradation of Neuronal Encoding of Speech in the Subthalamic Nucleus in Parkinson's Disease. *Neurosurgery.* 2018;84:378–387.
6. Jorge A, et al. Hyperdirect connectivity of opercular speech network to the subthalamic nucleus. *Cell Reports.* 2022;38:110477
7. Nambu A, Tokuno H & Takada M. Functional significance of the corticoÁ/subthalamoÁ/pallidal 'hyperdirect' pathway. *Neuroscience Research.* 2022:7