Supplementary Information to "An Intraoperative Study of Speech-Related Neuronal Activity in the Subthalamic Nucleus of Parkinson's Disease Patients"

Supplementary Results

Exclusive speech-related neurons

The activity of 61 neurons was locked to one or more aspects of speech (i.e., the corresponding statistical test yielded P-value less than 0.05): speech task onset, speech production onset, and/or speech production end (Fig. 4A). Based on the strongest relation (i.e., the one with the minimal P-value), we categorized speech-related neurons as exclusively speech cue onset-locked, exclusively speech production onset-locked, or exclusively speech production end-locked, ensuring that each neuron appeared in only one category. We identified 23 neurons as exclusively speech cue onset-locked (Fig. S2A), with 14 showing increased MIFR and 9 showing decreased MIFR. Similarly, we found 25 neurons locked exclusively to speech production onset (Fig. S2B), with 13 showing increased MIFR and 12 showing decreased MIFR. Lastly, 13 neurons were locked exclusively to speech production end (Fig. S2C), with 4 showing increased MIFR and 9 showing decreased MIFR.

Exclusive hand motor neurons

The activity of 54 neurons was locked to one or more aspects of hand motor task: motor task onset and/or motor action. Based on which relation was the strongest (i.e., that with the minimal P-value of the corresponding test), we categorized neurons as exclusively hand motor task onset-locked or motor task execution-locked neurons. Specifically, 22 neurons were locked exclusively to motor cue onset (Fig. S5A), with 15 of them increasing their firing rate and 7 decreasing their firing rate. Additionally, 32 neurons were locked exclusively to motor task execution (Fig. S5B), with 18 increasing their firing rate and 14 decreasing their firing rate.

Supplementary Figures

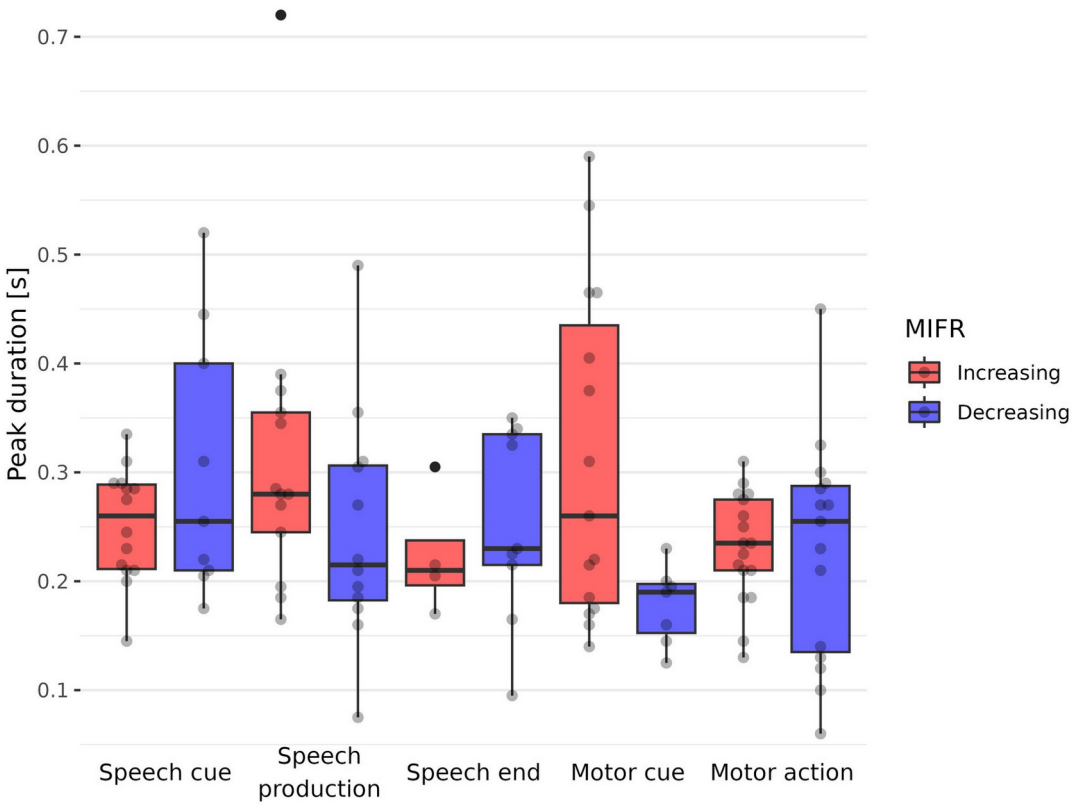

Figure S1. The duration of periods of altered mean instantaneous firing rate (MIFR) in STN neurons locked to different aspects of speech and motor function. Red (blue) boxplots depict neurons increasing (decreasing) their MIFR in response to specific events. The peak duration refers to the time interval around local maxima (or minima) in which MIFR was greater (or less) than the mean baseline MIFR.

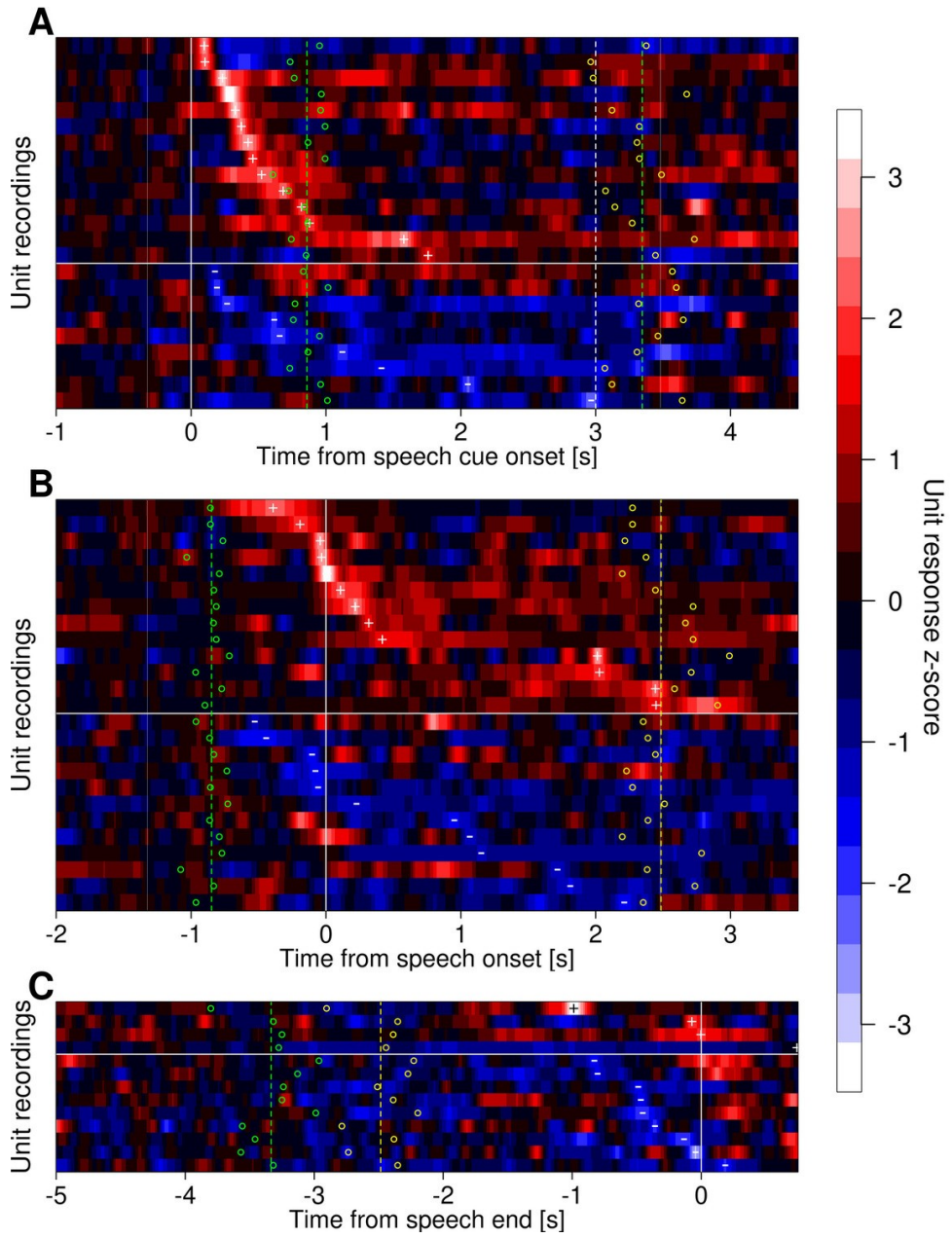

Figure S2. The activity of exclusive groups of STN neurons locked to various aspects of speech. (**a**), Speech cue-locked activity of 23 STN neurons exclusively related to speech cue onset, not speech production onset or end. Each row represents one neuron. Time 0 s represents the onset of speech cue. The '+' and '-' marks denote the times of the maximal and minimal MIFR, respectively. The neurons are sorted by increasing times of the extreme, with neurons that increased their activity listed first. The black color represents the mean baseline firing rate. For visualization purposes, the firing rate of each neuron was normalized to unit variance and had the mean baseline firing rate

subtracted. The green and yellow points denote the mean time of speech onset and offset, respectively. The vertical dashed lines denote the mean times of speech onset and offset. (**b**), Speech production-locked activity of 25 STN neurons exclusively related to speech production onset, not speech cue onset or speech production end. The green and yellow points denote the cue onsets and the speech offsets, respectively. The vertical dashed lines denote the mean time of cue onset and speech offset. **C**, The activity of 13 STN neurons exclusively related to speech production end, not speech cue onset or speech production onset. Time 0 s marks the end of production of the last KA syllable during speech. The green and yellow points denote the cue onsets and the speech onsets, respectively. The vertical dashed lines denote the mean time of cue onset and speech onset. MIFR = mean instantaneous firing rate.

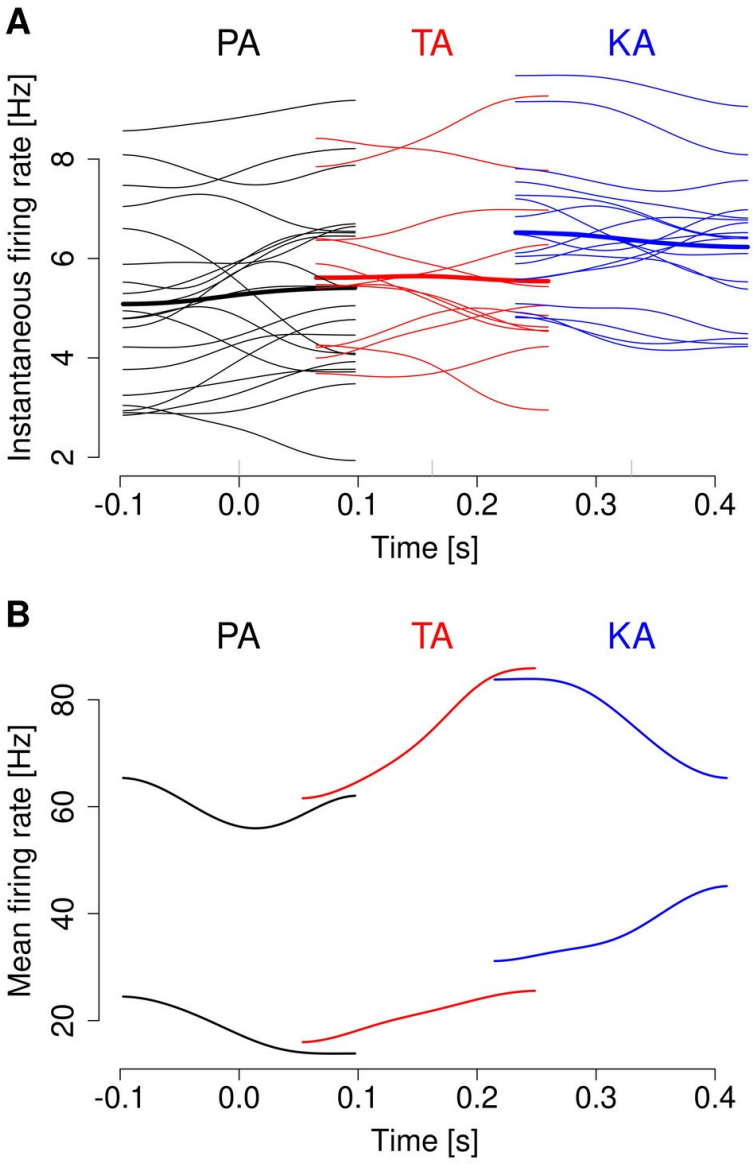

Figure S3. The activity of neurons responding to the production of the PA, TA, and KA syllables. (**a**), The firing in individual trials (thin curves) is overlaid with mean instantaneous firing rate (MIFR, thick curves). Note that the mean curves do not form a single continuous curve because they are based on different sets of syllable-specific neurons. However, on the population level, the neurons tended to increase their firing during the production of the PA syllable, sustain above-average firing during the production of the TA syllable, and decrease their activity during the production of the KA syllable. The MIFR of KA-related neurons was relatively highest. (**b**), The mean activity of 2 neurons that responded specifically to the production of all the PA, TA, and KA syllables. The firing in individual trials in 200ms wide windows is shown. Note that the curves do not form a single

continuous curve because they represent trial-averaged activity centered at variable syllable onsets. In contrast to the population-level activity, these two neurons decreased firing during the production of the PA syllable, increased firing during the TA syllable, and one decreased, but the other increased activity during the KA syllable.

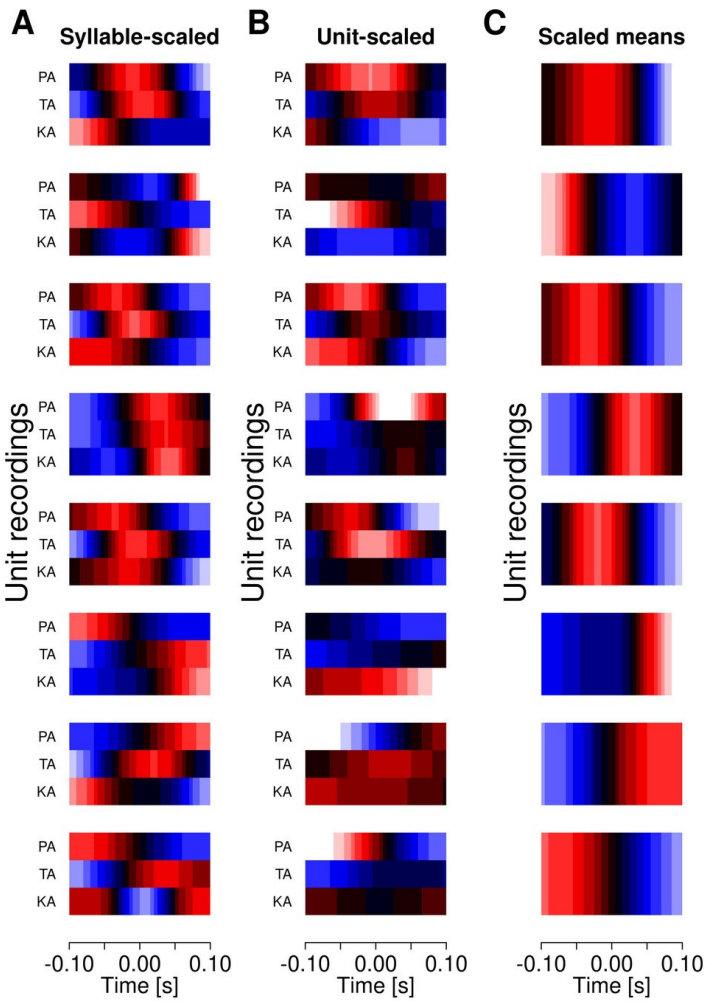

Figure S4. The MIFR of 8 neurons that responded non-specifically to the production of all the PA, TA, and KA syllables (i.e., similarly to all types of syllables on average). The neurons (units) are depicted in rows. For visualization purposes, normalized firing rates are shown. (**a**), MIFR was normalized for each neuron and syllable. (**b**), MIFR was normalized for each neuron only. (**c**), the averaged activity from (**b**) is shown. Note that the activity pattern of most neurons is specific to particular syllables. Also note that the averaged activity exhibits considerable diversity.

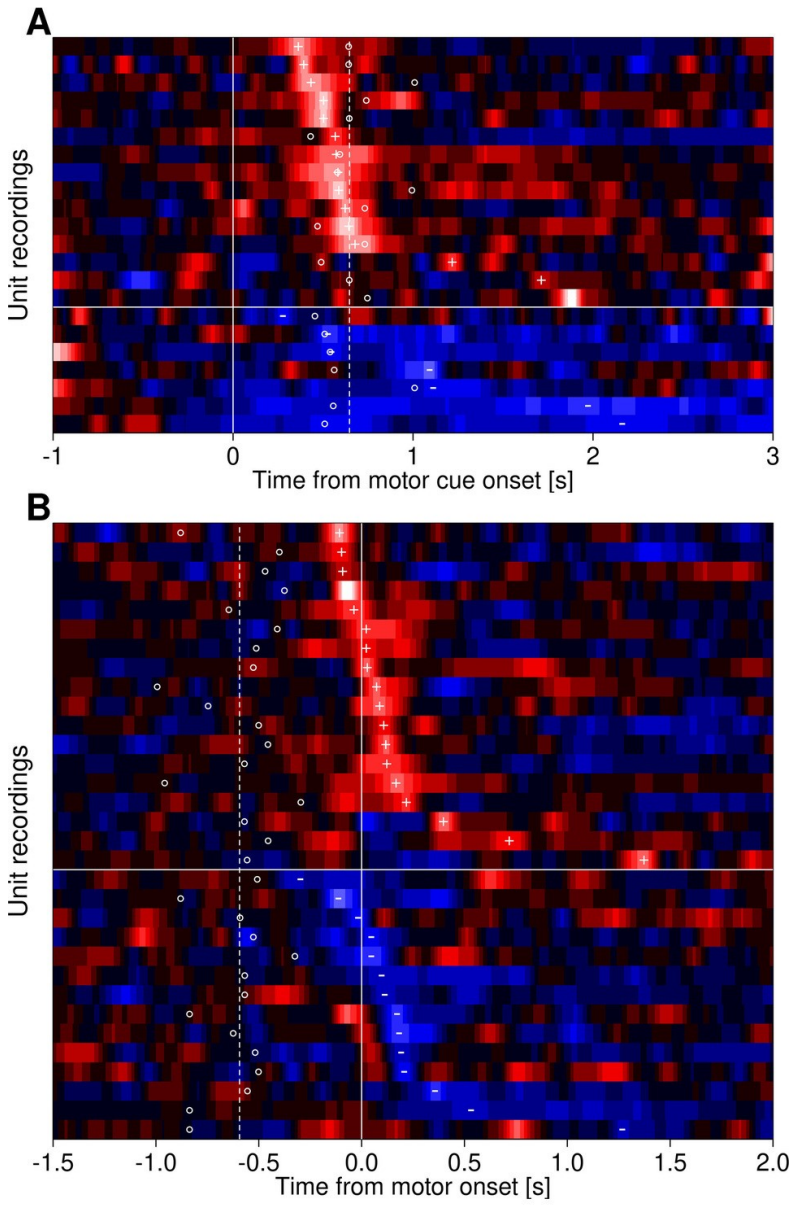

Figure S5. The activity of exclusive groups of motor-locked STN neurons. (**a**), Motor cue-locked activity of 22 STN neurons exclusively related to motor cues, not motor action. Each row represents one neuron. Time 0 s represents the start of the motor task, i.e., the time when the motor cue of appeared instructing the patient to press a button. The '+' and '-' marks denote the times of maximal and minimal MIFR, respectively, for each neuron. The black color represents the mean baseline MIFR. For visualization purposes, the firing of each neuron was normalized to unit variance and had the mean baseline MIFR subtracted. The white points denote the mean time of motor response, and the vertical dashed line denotes the mean time of the motor response. (**b**), Motor action-locked activity of 32 STN neurons exclusively related to motor action, not motor

cues. Time 0 s represents the time of button pressing. The white points denote the cue onsets. The vertical dashed line denotes the mean time of cue onset. MIFR = mean instantaneous firing rate.

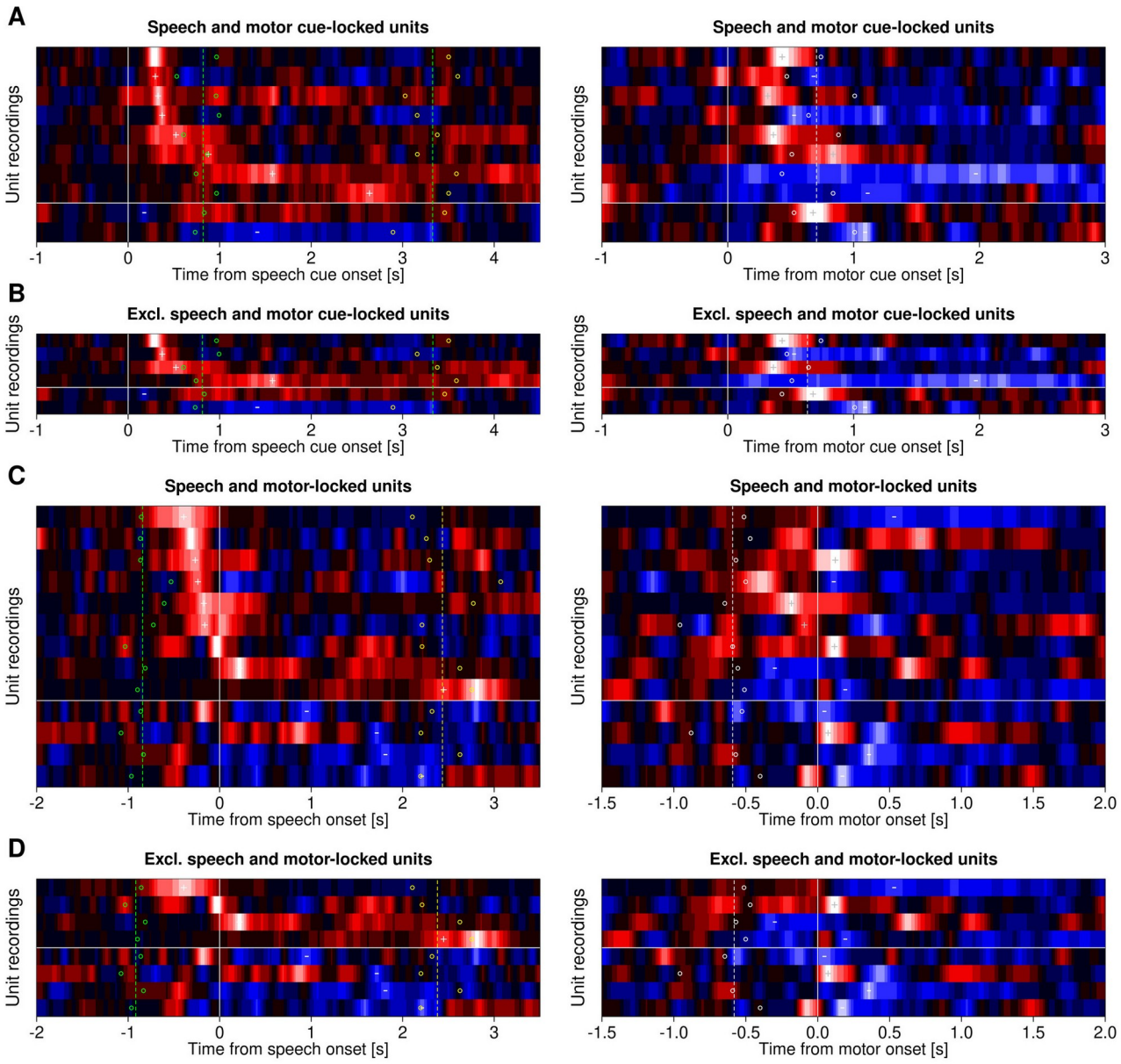

Figure S6. The activity of nonspecific visual cue-locked and action-locked STN neurons. (**a**), The activity of 10 STN neurons locked both to speech (left) and motor (right) cues. Each row represents one neuron. Time 0 s represents the onset of the speech (left) and motor (right) cue instructing the patient to start the corresponding activity. Eight neurons increased their firing rate during speech trials (left, top rows, red color), and two decreased their firing during speech trials (left, bottom, blue color). The '+' and '-' marks denote times of maximal and minimal firing rate, respectively, in each neuron. The black color represents the mean baseline firing rate. For visualization purposes, the firing rate of each neuron was normalized to unit variance and had the mean baseline firing rate subtracted. On the left, the green and yellow points denote the mean time of speech onset and offset, respectively, and the corresponding vertical dashed lines denote the mean times of

speech onset and offset. On the right, the white points denote the mean time of the motor response, and the vertical dashed line denotes the mean time of the motor response. Note that most neurons behave similarly on both the speech and motor trials. (**b**)**,** The activity of 6 STN neurons locked exclusively to both speech (left) and motor (right) cues (i.e., these neurons are not locked to speech production or motor action). Note that the character of activity was similar in only 3 neurons. (**c**), The activity of 13 STN neurons locked to both speech production (left) and motor action (right). Time 0 s represents the onset of the corresponding activity. (**d**), The activity of 8 STN neurons locked exclusively to both speech production (left) and motor action (right). Time 0 s represents the onset of the corresponding activity. Note that the character of activity was somewhat similar in only 4 neurons.