

Spectrogram and BOLD analysis of stop consonants in Parkinsonism

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Introduction: The motor incoordination in parkinsonian patients; i.e. Parkinson's disease (PD), Multiple system atrophy (MSA) and progressive supranuclear palsy (PSP) reflects degeneration in the dopaminergic neurons in the substantia nigra and basal ganglia. Speech is the vocalized (motor) form of communication that can be defined as the ability to form reproducible sounds with certain semantic meanings. The frequency of motor speech disorder in PD alone ranges from 75% to 89% and exhibit hypophonia repetition of syllables, dysphonia, vocal tremor, prosodic insufficiency leading to impaired speech.

Materials and Methods: Subjects fulfilling standard clinical diagnostic criteria were recruited from the movement disorder clinic of our institute (table 1). BOLD data were acquired covering the whole brain on 1.5T (Avanto, M/s Siemens Germany) using audio visual stimulus system (NordicNeuroLab, Norway). Single-shot echo planar imaging was used with the following parameters: number of slices: 31, slice thickness: 4.0 mm; TR: 4000 ms, TE: 44 ms, etl:127, FOV: 230mm and resolution: 128 x 128. Using a standardized block paradigm of 130 measurements, subjects were requested to read audibly, simple two syllable Hindi words belonging to the six articulatory stop consonant categories (namely velars, palatals, retroflexes, dentals, bilabials and nasals) during each active phase of ten measurements each (Fig.1) and alphabets were presented during baseline. SPM2 was used for processing the data. The BOLD clusters were converted from the MNI coordinates to Talairach and Tournoux co-ordinates, and the anatomical areas estimated. One way ANOVA ($p < 0.01$, cluster threshold 10) was used for group analysis. The voice samples of the subjects were also acquired using a Sony recorder and were analyzed using PRAT software.

Group	N	Subjects	Age	Duration	Dopa intake (mg)	Stage	MMSE	UPDRS III
PD	29	22M/ 7F	59.6 ± 5.34 ± 12.0	3.4	473.28 ± 175.7	H & Y 1.8 ± 0.6	27.14 ± 2.4	22.69 ± 11.16
MSA	20	13M/ 7F	61.5 ± 4.65 ± 6.9	5.9	373.36 ± 128.8	UMSARS 2.8 ± 1.0	28.1 ± 2.2	23.78 ± 14.7
PSP	15	13M/ 2F	63.0 ± 3.08 ± 6.9	2.3	357.7 ± 80.5	PSP rating 2.62 ± 1	26.85 ± 2.8	20.78 ± 6.0
Controls	38	22M/ 16 F	51.0 ± 7.4	-	-	-	29.0 ± 1.0	-

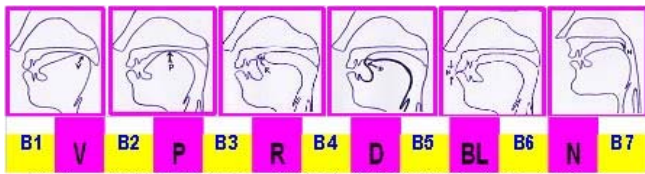


Figure 1. The articulatory stop consonants used in the speech paradigm

Results and Discussion: The BOLD activation pattern reflected an increased activation in the primary motor cortex in PD and MSA for velars, palatals, and retroflexes (Fig 2.). The supplementary motor area was hyperactive for velars and retroflexes in PD and MSA while no activity was observed for PSP in any of the speech categories. Lingual gyrus activation reduced in the order PD>MSA > PSP. For the velars, bilabials and nasals, lingual gyrus activation was less than the controls and absent for retroflexes. Activation in insula that facilitates articulatory planning was not observed in any of the patient groups. Formant means an acoustic resonance of the human vocal tract. Spectrograms, used to visualize formants represent four formant frequencies in humans i.e. F_0 : fundamental frequency from the vocal cords alone, F_1 : 300 Hz to 1000 Hz. The lower it is, the closer the tongue is to the roof of the mouth. F_2 : 850 Hz to 2500 Hz. F_2 value is proportional to the front-ness or back-ness of the highest part of the tongue during the reduction of the vowel. F_3 , F_4 and F_5 are also important in determining the phonemic quality of a given speech sound. Voice onset time (VoT), a feature of the production of stop consonants, is defined as the length of time that passes between when a stop consonant is released and when voicing. Spectrogram analysis (Fig. 3) shows a significant VoT increase for bilabials, retroflexes and velars and the values are higher in PSP patients. The mean intensities were higher for bilabials, dentals, retroflexes and velars. The F_2 frequency is affected for bilabials, dentals, nasals, and velars. These may reflect the narrowness of the resonating chamber due to tremors and rigidity in the tongue.

Conclusion: The speech dysfunction in such patients indicate that the retroflexes to be the most difficult in pronunciation. Absence of BOLD activation in the insula may explain dysarthria. This study presents a hierarchy in speech dysfunction among Parkinsonism.

References:

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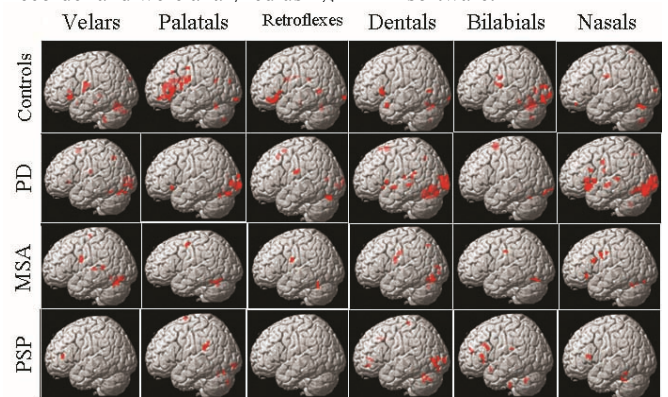


Figure 2. The BOLD activation pattern overlaid onto the rendered brain images for the articulation of stop consonants in parkinsonian subjects.

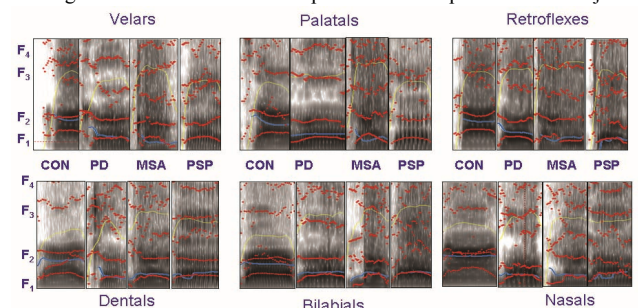


Figure 3. Spectrogram results for articulation of stop consonants in representative subjects.