Correlation between levodopa response and acoustic parameters of prominence marking as well as tongue body movements in patients with Parkinson's disease

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Introduction: Parkinson's Disease (PD) as a neurodegenerative disorder affects non-motor and motor functions due to a progressive loss of dopaminergic cells in the brain. Gross motor symptoms are manifested in smaller, slower and less extended movements and/or a resting tremor. On the speech level many patients develop a speech disorder entailing a slurred speech production due to slower and unprecise articulation (Duffy, 2013). While mild dysarthric patients reveal a reduced vowel space and hypoarticulation of vowels, they can mark prosodic prominence by modulating F0, intensity and vowel articulation in prominent positions, but the prosodic modifications are less efficient than in healthy control speakers (Thies et al., 2020).
Patients with PD are treated with dopaminergic medication such as levodopa, which raises the dopamine concentration in the brain to improve motor functions. Whereas it is proven that levodopa is an effective treatment for gross motor performance (Katzenschlager & Lees, 2002), it remains unclear to what extent it influences speech production. Therefore, this study investigates the influence of levodopa on speech performance of patients with PD based on acoustic and articulatory measurements.

Methods: Fifteen native German speaking patients with idiopathic PD were recorded with an Electromagnetic Articulograph (AG 501, Carstens system) within one recording session in two conditions: (1) without drug intake (med-OFF, 12 hours cessation of PD medication) and (2) with drug intake (med-ON, 30 minutes after taking 200 mg levodopa). The speech task was designed as a question-answer-scenario to elicit target words in three different focus structures: background, broad focus and contrastive focus. The target words were disyllabic girl names (CV.CV) with word stress on the first syllable. In total 12 target words consisting of 5 different cardinal vowels were recorded in each focus condition.
Prominence markers such as acoustic syllable durations, modulation of F0 and intensity were calculated. Moreover, tongue body movements of the vowel V1 as main domain of focus production were investigated by including the variables i) gestural duration, ii) displacement and iii) peak velocity of the vocalic tongue body movement in the accented syllable (Browman & Goldstein, 1986). In addition, patients' motor impairment was evaluated using the 'Unified Parkinson's Disease Rating Scale' (UPDRS III; Goetz et al., 2018) in med-OFF and med-ON condition. From the test scores we calculated the dopa response as percentages of motor improvement from OFF to ON condition.

Results: Preliminary results from twelve patients show that all patients responded well to the levodopa intake (dopa response: $\mu = -42.5\%$, $\sigma = 20.6$). Moreover, levodopa had an influence on some speech parameters. While the parameter intensity increases from med-OFF to med-ON ($p < .001$), acoustic syllable durations and the tonal range of F0 movements remain the same. Comparing med-OFF and med-ON condition on the articulatory level, the following changes are observable: Under medication, we find i) shorter vocalic gesture durations ($p < .05$) , ii) higher displacements ($p < .05$) and iii) higher maximal velocities ($p < .05$) for the tongue body movements during the production of all the five vowel types.

Moreover, we found evidence for prominence marking in med-ON and med-OFF condition. Syllable durations in accented syllables (broad, contrastive) are longer than in unaccented syllables (background, $p < .001$). Patients also mark prosodic prominence by producing a rising F0 contour ($p < .001$) and by increasing their intensity ($p < .001$). The modulation of syllable duration, F0 and intensity is higher in contrastive focus condition compared to broad focus condition revealing an increase of prosodic prominence. On the articulatory level, only an increase of gesture duration seems to be a parameter of prominence marking ($p < .001$).

Discussion: Our preliminary results demonstrate that levodopa has an influence on acoustic and articulatory parameters of speech production in patients with PD. Under medication, patients speak louder probably due to better control of respiratory muscles and improved pulmonary function (Monteiro et al. 2012). Further, they produce shorter, larger and faster tongue body movements in med-ON condition compared to med-OFF. This points to the fact that levodopa improves not only gross motor skills but also speech motor skills.
Moreover, our data confirms that patients with PD can mark prosodic prominence with and without medication in terms of tonal marking and hyperarticulation of the accented syllables. In line with Thies et al. (2020), they increase syllable duration, modulate intensity and F0 height and change also vowel articulation. Further, it is noticeable that levodopa mainly affects articulatory parameters, while prominence marking is realized on the acoustic level.

Conclusion: Patients with Parkinson's disease mark prosodic prominence by changing tonal and articulatory parameters from background to broad focus to contrastive focus condition. The data suggests that levodopa has an influence on patients' speech performance by producing sounds more efficiently and precisely and by improving the modulation of prosodic prominence markers in med-ON condition.

References

Browman, C. P. & Goldstein, L. (1986). Towards an articulatory phonology. Phonology, 3(1), 219-252.

Duffy, J. R. (2013). Motor Speech disorders-E-Book: Substrates, differential diagnosis, and management. Elsevier Health Sciences.

Goetz, C. G., & the Movement Disorder Society Task Force on Rating Scales for Parkinson's Disease (2008). Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale: Scale presentation and clinimetric testing results. Movement Disorders, 22, 2129–2170.

Katzenschlager, R., & Lees, A. J. (2002). Treatment of Parkinson's disease: levodopa as the first choice. Journal of neurology, 249(2), ii19-ii24. DOI: 10.1007/s00415-002-1204-4

Monteiro, L., Souza-Machado, A., Valderramas, S., & Melo, A. (2012). The effect of levodopa on pulmonary function in Parkinson's disease: a systematic review and meta-analysis. Clinical therapeutics, 34(5), 1049-1055.

Thies, T. et al. (2020). Prominence marking in parkinsonian speech and its correlation with motor performance and cognitive abilities. *Neuropsychologia, 137*(3),107306.