Kinematic and acoustic contributors to formant perturbation responses in individuals with and without Parkinson's disease

Rationale and purpose

Auditory perturbation tasks provide insight into the use of auditory feedback during speech, which is useful for understanding the nature of speech disruptions in individuals with Parkinson's disease (IwPD). Two prior studies examined responses to a gradual auditory perturbation in formant frequencies of a vowel in IwPD compared to control speakers (CS), with one study finding no significant differences between IwPD (*on* levodopa) and CS (Abur et al., 2021), and the other finding reduced adaptive responses in IwPD (*off* levodopa) (Mollaei et al., 2013). Both studies examined speech acoustics alone, raising the question of whether articulatory kinematics (i.e., movements of the tongue) may demonstrate motor changes that are not captured acoustically.

Hence, the present study assesses the relationship between acoustic (formants) and kinematic (vertical tongue tip movement) responses to a gradual formant perturbation in IwPD and CS. As our group of IwPD was tested *on* levodopa, we hypothesised that there would be no significant acoustic differences between IwPD and CS in how they respond to the formant perturbation (following Abur et al., 2021). Due to a lack of prior research, we had no a priori hypothesis regarding kinematic differences between IwPD and CS.

Method

The present study is part of a larger study approved by the Medical Ethics Review Board of the institution.

Participants

We tested 28 native Dutch speakers, namely 14 IwPD (7 female, 7 male; $M = 68.7$, $SD = 6.7$) and 14 age- and sex-matched control speakers ($M = 69.5$, $SD = 6.6$).[1] All participants scored 22 or higher on the Montreal cognitive assessment (Nasreddine et al., 2005).

IwPD had been diagnosed with idiopathic Parkinson's disease between 1 and 17 years ago, with mild to severe motor symptom severity (16–83 points via MDS-UPDRS part III; Goetz et al., 2008).

Procedure

Participants completed a 120-trial adaptive formant perturbation task (baseline, ramp, hold, after-effect), during which the first formant (F_1) was gradually decreased by 20% and the second formant (F_2) increased by 15% using Audapter (v2.1.012; Cai et al., 2010). The task included six target words with target vowel /ɛ/, which all shifted into real words with vowel /ɪ/. Auditory feedback in the earphones was amplified ~5dB relative to the microphone signal.

We simultaneously collected electromagnetic articulography data with an NDI-VOX at 400Hz with one tongue sensor, one jaw sensor, and two lip sensors (following Rebernik et al., 2021).

Data preprocessing and statistical analysis

Audio data of the participants' productions was annotated in Praat v6.1.42 and kinematic data head-corrected in MATLAB R2021a. Acoustic and kinematic data were time-aligned using an in-house R script, and the mean F_1 and F_2 frequencies (in Hz) as well as mean tongue tip height

[1]Data from a total of 60 participants (30 IwPD and 30 CS) has been collected and is currently being analysed.

coordinates (TT$_y$; in mm) were calculated across the 40-120ms of each production. Data was statistically analysed in R Studio (R version 4.3.1), using Generalized Additive Mixed Modelling (GAMM; Wood, 2017), with which we assessed the non-linear effect of trial on F_1, F_2 and TT$_y$ (per group), while accounting for participant and stimulus variability. The alpha level was set at $\alpha = 0.05$.

Results & Discussion

F_1 and F_2 responses across trials in the RAMP and HOLD phases did not significantly differ between the two groups, with both groups of participants increasing their F_1 and decreasing their F_2 in response to the F_1 decrease and F_2 increase, respectively. However, TT$_y$ was significantly different between the groups ($p = 0.008$), with IwPD raising their tongue in response to the perturbation and CS lowering it (Fig. 1).

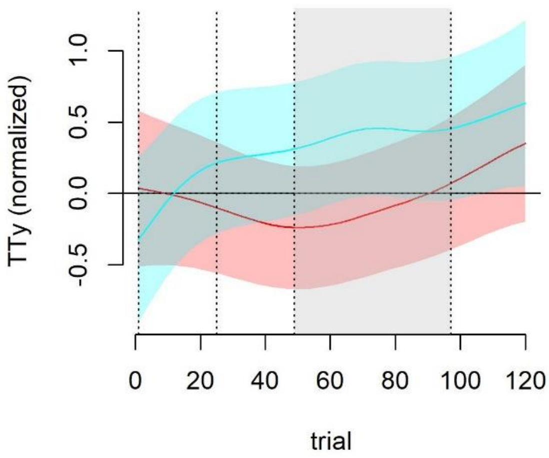

Figure 1: Difference in tongue tip trajectory across trial (blue: IwPD, red: CS; shaded grey area represents the HOLD phase)

Current results therefore suggest that acoustic measures (F_1 and F_2) are not sufficient to capture differences between IwPD and CS present in the kinematic data (TT$_y$) during a formant adaptation task. Data analysis is ongoing for the full set of collected participants (N = 60) and will include an assessment of relationships between acoustics, kinematics, and disease severity within the group of IwPD. Variability in hearing screening results, age, and sex will be taken into account in our exploratory analysis.

References

Abur, D., Subaciute, A., Daliri, A., Lester-Smith, R. A., Lupiani, A. A., Cilento, D., Enos, N. M., Weerathunge, H. R., Tardif, M. C., & Stepp, C. E. (2021). Feedback and feedforward auditory-motor processes for voice and articulation in Parkinson's disease. *Journal of Speech, Language, and Hearing Research.* https://doi.org/10.1044/2021_JSLHR-21-00153

Cai, S., Ghosh, S. S., Guenther, F. H., & Perkell, J. S. (2010). Adaptive auditory feedback control of the production of formant trajectories in the mandarin triphthong /iau/ and its pattern of generalization. *The Journal of the Acoustical Society of America*, *128*(4), 2033–2048. https://doi.org/10.1121/1.3479539

Goetz, C. G., Tilley, B. C., Shaftman, S. R., Stebbins, G. T., Fahn, S., Martinez-Martin, P., Poewe, W., Sampaio, C., Stern, M. B., Dodel, R., Dubois, B., Holloway, R., Jankovic, J., Kulisevsky, J., Lang, A. E., Lees, A., Leurgans, S., LeWitt, P. A., Nyenhuis, D., Olanow, C. W., Rascol, O., Schrag, A., Teresi, J. A., van Hilten, J. J. and LaPelle, N. (2008). Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): Scale presentation and clinimetric testing results. *Movement Disorders*, *23*(15), 2129–2170. https://doi.org/10.1002/mds.22340

Mollaei, F., Shiller, D. M., & Gracco, V. L. (2013). Sensorimotor adaptation of speech in Parkinson's disease. *Movement Disorders*, *28*(12). https://doi.org/10.1002/mds.25588

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Rebernik, T., Jacobi, J., Jonkers, R., Noiray, A., & Wieling, M. (2021). A review of data collection practices using electromagnetic articulography. Laboratory Phonology: Journal of the Association for Laboratory Phonology, 12(1), 6. https://doi.org/10.5334/labphon.237

Wood, S. N. (2017). *Generalized additive models: An introduction with R*. Taylor & Francis.