A COUSTIC ANALYSIS OF SPEECH AS A PROMISING INSTRUMENT FOR MONITORING AND DIFFERENTIAL DIAGNOSIS OF PARKINSONS’S DISEASE

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Abstract: Parkinsonian speech is characterized by abnormally low voice intensity, with vocal decay, poor voice quality, reduced prosodic pitch and loudness inflection, imprecise vowels and consonants, dysrhythmia and short rushes of speech, mumbling, and reduced speech intelligibility. Recently, there have been new acoustic analysis methods to capture different aspects of these speech abnormalities. In this review, selected studies are summarized in order to illustrate the application of acoustic analysis of speech for the objective measurement and quantification of different aspects of Parkinsonian dysarthria.

Keywords: Parkinson’s disease, acoustic analysis of speech, hypokinetic dysarthria, dysprosody, vowel articulation, syllable repetition, motor speech performance

I. INTRODUCTION

Parkinson’s disease (PD) is a neurodegenerative disorder characterized by progressive loss of dopaminergic neurons, primarily in the substantia nigra pars compacta, [1]. According to the Braak staging, PD begins as a synucleopathy in non-dopaminergic structures of the lower brainstem or in the olfactory bulb with subsequent rostral progression and affection of the substantia nigra [2]. The progressive dopaminergic loss is associated with a variety of motor and non-motor deficits in PD patients. In addition to the most ostensible symptoms as muscular rigidity, tremor, bradykinesia and postural instability, many patients develop a distinctive alteration of speech characterized as hypokinetic dysarthria. In a survey, the prevalence of dysarthria in PD was about 70% [3]. Dysarthria can emerge at any stage of the disease and worsen in the later stages [4, 5], causing a progressive loss of communication and leading to social isolation. Based upon the perceptual analysis of a large sample of dysarthric speakers, Darley, Aronson and Brown primarily defined a salient cluster of deviant speech dimensions in Parkinsonian dysarthria including a harsh breathy voice quality, reduced variability of pitch and loudness, reduced stress, imprecise consonant articulation and short rushes of speech interrupted by inappropriate periods of silence [6, 7]. Together, these features give hypokinetic dysarthria its distinctive gestalt of a flat, attenuated and sometimes accelerated quality [6, 7]. Logeman and colleagues established a general profile of hypokinetic dysarthria in a group of 200 PD patients, where almost 90% had voice disorders characterized by hoarseness, roughness, tremulousness and breathiness [8]. About half of the speakers featured articulatory problems, and 20% had speech rate abnormalities characterized by syllable repetitions, irregularities of syllable length and excessive speech pauses. According to this study, the authors supposed voice abnormalities to be the prominent attribute of hypokinetic dysarthria with the assumption of further subgroups including articulatory and speech rate deviations. In a further investigation on a large group of PD patients performed by Ho and colleagues, voice impairment was present even in the early stages of the disease with additional articulatory deficits and disturbance of fluency in the more advanced stages of PD [4]. Though, changes of speech rate and regularity were also observed in a subgroup of only mildly affected patients leading to the hypothesis that fluency deficits might be an isolated feature of hypokinetic dysarthria independent from voice and articulatory impairment [4]. Since this first systematic characterization of hypokinetic dysarthria, there has been a wealth of subsequent investigations based upon perceptual, acoustical and electrophysiological methods which further refined the description of speech disturbance in PD. However, although there is some evidence for a manifestation of hypokinesia and muscular rigidity of the vocal tract, there is still ambiguity concerning the pathophysiological mechanism of the different aspects of Parkinsonian speech disturbance in detail.

In this presentation it will be shown, that acoustic analysis of voice and speech in PD and related movement disorders may be a helpful instrument to gain further insight into the underlying pathophysiology by objective and quantifiable measurement of distinctive speech parameters and might therefore serve as a “window into the disease”.

II. METHODS

In the different investigations, acoustic analysis of speech was based upon a standard reading task consisting of four complex sentences [9, 10, 11] or a simple syllable
repetition paradigm where participants were asked to repeat a single syllable in a self-chosen steady pace [12, 13]. Speech samples were digitally recorded and analyzed using the software PRAAT [14]. For the description of intonation, fundamental frequency variability (F0SD) and fundamental frequency range were applied. Aspects of speech velocity and fluency were illustrated by total and net speech rate (TSR and NSR), pause ratio (PR%) and the fraction of intra-word pauses related to overall speech pauses (Pinw%). Furthermore, the acceleration of speech rate in the course of reading was defined as articulatory acceleration (AA). The vowel articulation index (VAI) first established by Roy and Sapir [15] was used for the measurement of vowel articulation. Concerning syllable repetition capacity, the relative coefficient of variance of syllable length (COV) was introduced as a measure of steadiness in the course of the performance.

Participants consisted of different samples of patients with PD, age- and gender-matched healthy speakers and – in one investigation – of patients with progressive supranuclear palsy (PSP). At the time of examination, all patients were under stable dopaminergic medication. Global motor impairment of all patients was rated according to the Unified Parkinson’s Disease Rating Scale (UPDRS) and Hoehn&Yahr stages.

### III. RESULTS

#### A. Progression of dysprosody in PD over time [9]

In a group of 50 patients with PD which were tested and re-tested after at least 12 months (mean 25 months) according to the reading task, TSR and NSR declined from first to second examination, especially in the male patients, but showed no significant differences to the control group. The course of pitch variation revealed some gender particularities. Whereas female patients’ pitch variability declined over time, male patients’ intonation variability remained relatively stable. F0SD in male and female patients with PD were significantly reduced compared with the control group in the first examination and the follow up as well. Progression of prosodic impairment over time showed no correlation to disease duration or UPDRS motor score.

#### B. Vowel articulation in PD [10]

In a group of 68 patients with PD with mild dysarthria (1 point according to the "speech" item 18 of UPDRS) and 32 age-matched control persons, vowel articulation and speech rate were measured. F1 and F2 frequency values of the German vowels /a/, /i/, and /u/ were extracted from defined words within the reading text. Description of vowel articulation was based on measures of VAI. As main results, VAI values were significantly reduced in male and female PD patients as compared with the accordant control group. NSR was negatively correlated to VAI only in female PD speakers. No correlations were seen between vowel articulation and UPDRS and stage of disease. Obviously, some aspects of altered speech performance in PD seemed to feature some gender-specific patterns.

#### C. Acoustic analysis in PSP [11]

Based upon the reading task, 26 patients with PSP were examined in comparison to a group of 30 patients with PD. In the PSP group, NSR, F0SD and Pinw% (as a measure of precision of consonant articulation) were significantly reduced, whereas %PR was prolonged as compared with the PD group. Only in the male PSP patients, vowel articulation was found to be impaired. Global speech performance – as rated by perceptual impression – was worse in the PSP group in comparison with the PD group and showed a correlation to some distinct speech dimensions obtained by acoustic analysis.

#### D. Stability of syllable repetition in PD [12]

Based upon the syllable repetition task, 73 patients with PD and 43 healthy speakers were tested concerning the capacity to steadily repeat a single syllable (/pa/) in a self-chosen isochronous pace. COV of interval length and the change in interval length with successive utterances were measured for the description of pace stability throughout the performance. Then, participants had to identify irregularities of 30 played-back audio tests. Patients with PD showed significant difficulties in steadily executing a syllable repetition task with a significant elevation of COV and showed a clear tendency to pace acceleration in the course of the performance. However, there were no differences in the correct auditory identification of rhythm irregularities between the PD group and controls. As compared to healthy controls, the PD group featured disabilities in performing a steady sequence of utterances, which cannot be explained solely by impaired acoustical feedback mechanisms. The pattern of pace disturbance showed similarities with the finding of speech acceleration and rhythm irregularity in the course of reading or more complex conversational speech and therefore might share the same pathophysiology.

#### E. Instability of syllable repetition in the course of the disease [13]

As previously shown, Parkinsonian speakers show a tendency to articulatory acceleration and have difficulties to keep the steady pace of repeated syllables. The aim of the subsequent study was to analyse the stability of motor speech performance based upon the syllable repetition
paradigm during the course of disease to find a potential marker of disease progression in PD. 58 patients with PD and 35 controls were tested and re-tested after at least 12 months (mean 33.40 months). In the PD group, motor impairment was similar at first and second visit. Participants had to repeat the syllable /pa/ in a self chosen steady pace. Besides the calculation of COV as a measure of instability of repetition, the “percental pace acceleration in the course of the performance” (%PA) was further introduced. Patients with PD showed a significant elevation of COV and %PA indicating an instability of syllable repetition and a tendency to pace acceleration in the course of performing. Furthermore, in the PD group, COV and %PA showed a significant deterioration from first to second examination. Instability of steady syllable repetition in PD showed characteristic changes during the course of the disease, but no correlation with general motor impairment.

IV. DISCUSSION

The aforementioned investigations can serve as an example for the application of acoustic analysis of speech in PD. Since certain parameters of dysprosody and stability of syllable repetition feature distinct patterns of deterioration in the course of disease and seem to be independent from global motor impairment, these speech variables might have the potential to serve as marker of disease progression. Furthermore, vowel articulation as measured by VAI seemed to be impaired even in Parkinsonian patients with only mild dysarthria (when perceptually rated) and might therefore turn out to become a useful tool for the early detection of subclinical speech impairment in PD.

Instability of syllable repetition in PD might be interpreted as dysfunction of planning, preparing and executing basic motor speech sequences which share some similarities with the impaired execution of repetitive limb movements and therefore might indicate a shared pathophysiology. In a small series of patients, acoustic analysis of several distinct speech variables was able to differentiate Parkinsonian speakers from patients with PSP. Since in PSP, the neuropathological changes are more widespread than in PD, comprising basal ganglia as well as pontine and further brainstem and sometime cerebellar regions, the resulting dysarthria in PSP is more severe and may include hypokinetic, spastic and ataxic components which might be detected by acoustic analysis of speech.

One main limitation of the presented investigations might be the fact that all patients were under dopaminergic medication at the time of the examination and therefore, therapeutic or detrimental effects of the medication on the different speech variables cannot be ruled out. However, according to previous studies of our group, instability of syllable repetition on the one hand and several further speech parameters had shown no significant changes under short- and long-term dopaminergic stimulation [16, 17]. These findings justify the hypothesis that certain aspects of Parkinsonian dysarthria are independent from dopaminergic transmission.

V. CONCLUSION

According to the exemplified studies, acoustic analysis of speech in PD and related disorders might serve as a non-intrusive and easy applicable instrument for the measurement and monitoring of different speech dimensions. Furthermore, it might be helpful to generate and verify hypothesis about pathophysiological relations between speech and general motor performance in PD and might therefore serve as a “window into the disease”.

REFERENCES