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Measurement of Tremor in the Voices of Speakers with Parkinson's Disease

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Abstract

A study is presented analyzing tremor in the voice of speakers that were diagnosed with Parkinson's disease (PD). The examined sounds are sustained /a/s, originating from a large dysarthric speech corpus. Six measures of vocal tremor are extracted from these vowels by applying a self-developed algorithm that is based on autocorrelation of contours and implemented as a script of an open-source speech analysis program. Univariate analyses of covariance reveal significantly raised tremor magnitudes (tremor intensity indices and tremor power indices) in PD speakers off medication as compared to a control group as well as within PD speakers in off medication condition as compared to on medication. No significant differences are found between the control group and PD speakers on medication as well as for tremor frequencies. However, the greater part of variance in tremor measures is always accounted for the speakers' age.

Keywords: vocal tremor; acoustic measurement; Parkinson's disease; age dependency

1. Introduction

Parkinson's disease (PD), also idiopathic parkinsonism, is a neurodegenerative disorder of the central nervous system, which is mainly destroying the substantia nigra. This seriously impairs the secretion of the neurotransmitter dopamine and that in turn affects emotion, cognition as well as autonomous and motor neuronal activity. Relative motor inactivity or increased latency leads to one of the main symptoms of PD, if not the most formative one: tremor (commonly shake, tremble), an unintentional muscular control deficit that results in cyclic movement deviations. It was not by accident that James Parkinson himself named "his" disease "shaking palsy".

Functionally speaking, all tremor causing phenomena can be seen as disturbances of or latencies in the neuronal regulation of a muscular process, e.g. the production of speech. The production of speech, especially the process of

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phonation, probably is the fastest and most complex motor activity that humans are capable of. Thus, if there is a neuronal deficit that is generally causing tremor, then it should affect phonation. Vocal tremor is often defined as an *unintentional* low-frequency modulation of the vocal fold vibration. If intentionally used in singing, such modulations are known as vibrato. And an acoustic speech signal may also show further "tremulous" components that are e.g. due to articulatorily motivated jaw movements. Thus, for a reliable measurement of vocal *tremor* in natural voices, a vowel (e.g. /a/) phonation that should be sustained as constantly as possible is to be preferred.

Though, unlike other tremors the acoustic representation of vocal tremor channels into two components: A frequency and an amplitude tremor. And probably all of the neuronal disturbances or latencies of voice production are interweaved in both tremor types. That entails the fact that vocal tremor also can be observed as a symptom of other diseases as well as in healthy people, e.g. as a consequence of aging (as far as there is healthy aging at all – neurotransmitters are dramatically reduced by aging). Thus, diagnosing vocal tremor alone does not allow to refer unambiguously to any underlying cause. But on the other hand this comprises also the power of vocal tremor analysis as an additional tool for the determination or diagnosis of a wide variety of phenomena and diseases and especially PD [1].

However, as a look into recent literature reveals, the effect of PD on vocal tremor is still not too clearly understood. Speech pathologists [2, p. 41, our translation] state: "Indeed, this phenomenon [tremor] should not constitute an outstanding feature of hypokinetic dysarthria [...] and moreover should be bound to advanced stadia of disease [...]." And a little further on, special tremor frequencies around 9 Hz are suspected to indicate PD. Support for the relevance of tremor frequencies comes from a very recently published comprehensive study [3] involving 30 PD speakers and a control group that finds the frequency of amplitude tremor to be the only acoustic tremor measure that differs significantly between PD speakers and a control group – but within the PD group the mean value of amplitude tremor frequency lies below 5 Hz. In addition the author discovers that "acoustic voice tremor did not relate in any significant way to PD disability or phenotype." But she also finds that PD speakers "were more likely to show greater auditory perceived [...] magnitude[s] of frequency and amplitude tremor in comparison to controls, however without statistical significance" (sic!). Other speech researchers [4] have found acoustic tremor magnitude measures depending rather sensitively on PD, but not tremor frequency. Yet others [5] have tested 132 acoustic dysphonia measures with different classification algorithms in order to predict PD. They reached at best 98.6% accuracy (with 10 remaining features) – but without any (direct) tremor measure being involved.

Nomenclature

F_0	fundamental frequency (as a function of time)
A	amplitude (as a function of time)
$FTrF$	frequency tremor frequency – frequency of the strongest low-frequency modulation of F_0
$ATrF$	amplitude tremor frequency – frequency of the strongest low-frequency modulation of A
$FTrI$	frequency tremor intensity index – intensity/magnitude of the strongest low-frequency modulation of F_0
$ATrI$	amplitude tremor intensity index – intensity/magnitude of the strongest low-frequency modulation of A
$FTrP$	frequency tremor power index – power index of the strongest low-frequency modulation of F_0
$ATrP$	amplitude tremor power index – power index of the strongest low-frequency modulation of A

2. Data – the AHN corpus

The examined data are a subset of the data referred to as Aix Hospital Neurology (AHN) corpus [6]. Although this corpus also comprises other pathologies than PD and other data, e.g. absolute SPL and airflow, this study concentrates only on acoustic signals, more specifically on sustained /a/-vowels from 363 speakers, recorded in mono with a resolution of 16 Bit at a sampling frequency of 25 kHz. 239 of these speakers (83 females, 156 males) are diagnosed with PD and 124 (73 females, 51 males) are control speakers without any pathology. Within the PD group most (228) individuals were recorded under two conditions, on and off medication (L-DOPA, respectively Levodopa) that is administered in order to compensate for the decrease of the dopamine level.