ACOUSTIC TREMOR MEASUREMENT: COMPARING TWO SYSTEMS

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I. INTRODUCTION

The acoustic measurement of vocal tremor bears a high potential to serve for early diagnosis of several, mostly neuro-degenerative diseases like Parkinson's, Alzheimer's, multiple sclerosis, etc. Tremor often is defined as involuntary cyclic movement (deviation) of the limbs. But, (at least) if it is caused by deficits of the central nervous system, it is most likely that speech production is affected too, since the production of speech involves the coordinated processing of about 1,400 motor commands per second. So, the more than 80 muscles of the vocal apparatus may all show tremor and thus vocal tremor may have many sources. But once the acoustic output is investigated, all of these organic modulation sources combine to only two types of tremor: (subsonic) quasi-cyclic modulations of the frequency and of the amplitude. And the acoustic signal may easily be captured.

In spite of the potential of auditive or acoustic vocal tremor assessment, its reliability and therewith its validity still provide great room for improvement. Hence, the aim of this study is to compare two acoustic tremor measurement systems according to their (criterion) validity, that is here defined as goodness in measuring synthetically generated and thus known tremor.

II. METHODS

Acoustic synthesis of the test stimuli with known tremor properties in three steps: A completely synthetic sustained vowel is created by formant synthesis. (1) The glottal source signal (3s duration, 200Hz mean fundamental frequency) is modelled according to [1] and then (2) filtered by a time-invariant 'female'-/a/-shaped filter function. This /a/-sound serves as the carrier for the frequency and amplitude modulations. (3) These modulations are done by re-synthesis according to the overlap-and-add method [2]. Both modulation types are modelled with a sinusoidal shape that is varied in frequency and amplitude, resulting in 4 synthesis arguments: the frequency tremor frequency (FTrF[Hz]), the amplitude tremor frequency (ATrF[Hz]), the (relative) frequency tremor intensity (FTrI[%]), and the (relative) amplitude tremor intensity (ATrI[%]). Each argument is varied in 4 equally spaced steps across each range of naturally occurring values. Additionally, both a frequency and an intensity decline are synthesized in order to also simulate these naturally occurring effects. Thus, 4^6 = 4,096 test sounds result from a total variation of these 6 arguments. All 3 synthesis steps as well as the arguments' variation are implemented as a Praat [3] script.

The tremor measurement systems: The two compared systems are (1) the Multi-dimensional Voice Program (MDVP) [4] and (2) tremor.praat, version 3.01, a revised version of [5], including some newly developed tremor measures. MDVP is a commonly known and widely used voice quality measurement tool. Its standard procedure extracts 4 tremor measures that should correspond to the above mentioned synthesis arguments (MDVP is proprietary software, thus computational details are not known): The frequency of the strongest low-frequency modulation of the fundamental frequency (Fftr[Hz]) or respectively of the amplitude (Fatr[Hz]), and the (mean) magnitude of the strongest low-frequency modulation of the fundamental frequency (FTRI[%]) or respectively of the amplitude (ATRI[%]). tremor.praat extracts 14 tremor measures. 4 out of these 14 meet the definitions of the above named MDVP measures, i.e. they also correspond theoretically to the synthesis arguments and are named like them. tremor.praat is open-source software and implemented as a Praat [3] script.

Statistical methods: In order to assess the dependence of the 8 measured values on the values that are set by synthesis, 8 simple linear regressions are computed. Their determination coefficients (R^2) denote the proportion of variance in the measured values that can be explained by the set values' variance, thus they may serve as coefficients of validity of the measurement instrument. 99.99% confidence intervals (CIs) around these coefficients are calculated in order to indicate if (the populations of) corresponding coefficients differ from another.

III. RESULTS

The results of the regression analyses are shown in Fig. 1:

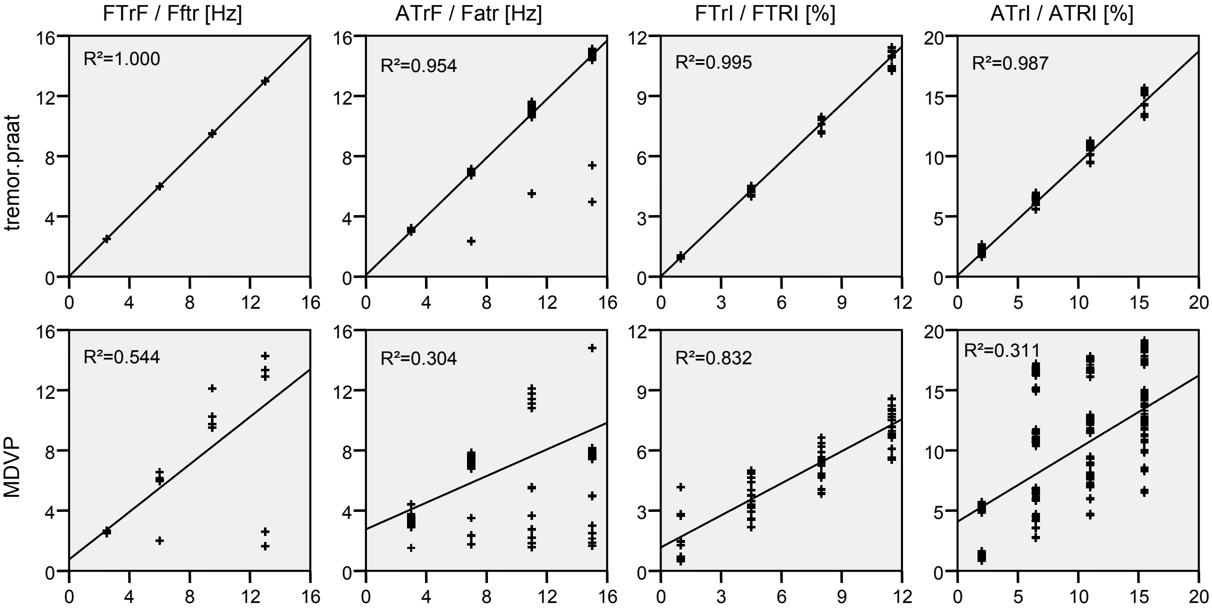

Figure 1: Scatterplots showing the measured values (ordinates) as a function of the values that were set by synthesis (abscissae). The lines are the linear regression models.

MDVP fails to extract amplitude tremor measures in 513 cases and frequency tremor measures in 256 cases. Although tremor.praat achieves to extract all measures from all sounds, its errors are highly significantly smaller, i.e. its measures are highly significantly more valid than those of the MDVP. tremor.praat's measurement of FTrF is (nearly) totally valid: The regression line fits all data points and equals the coordinate system's angle bisector. Also, the other tremor.praat measures can be considered excellent. In contrast the MDVP's extractions exhibit considerably more and greater measurement errors.

IV. DISCUSSION

Although tremor.praat is still under development, it has been shown that it is already (far) more valid in measuring vocal tremor than the standard program MDVP. Thus, it can only be advised to use tremor.praat for acoustic tremor measurement. Furthermore, formerly gained results that were based on the MDVP's tremor measures are very likely to improve in precision (and variety) if they were re-measured with tremor.praat.

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