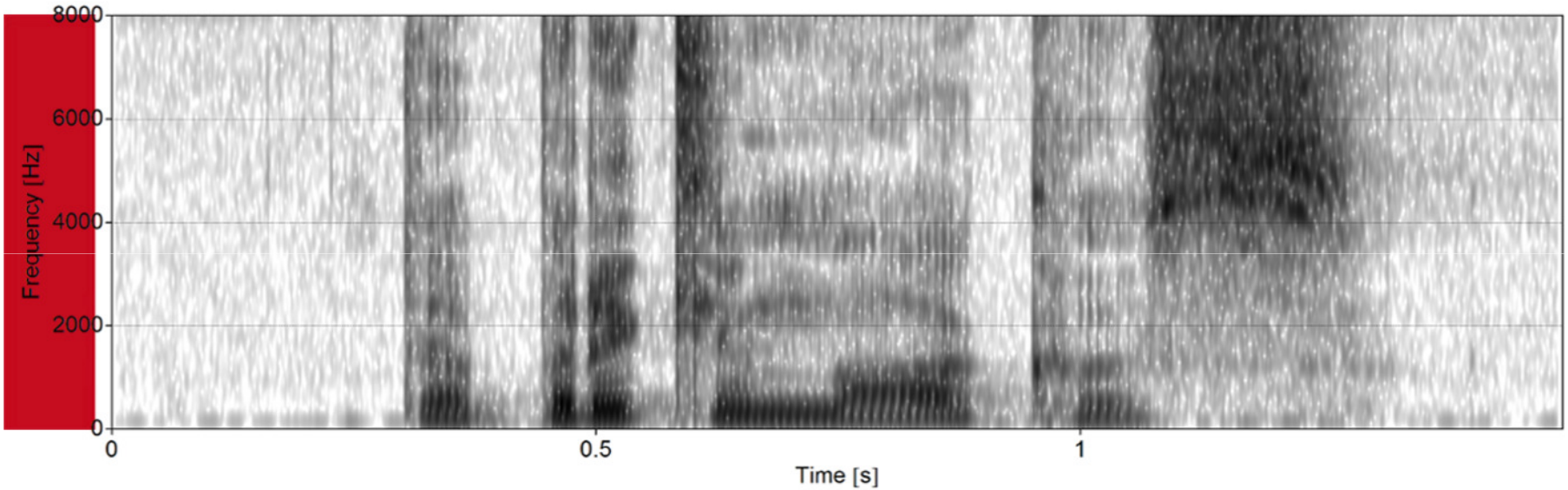

Measurement of Tremor in the Voices of Speakers with Parkinson's Disease

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Outline

1. Introduction
2. Data – the AHN corpus
3. Acoustic measurement of vocal tremor
4. Statistical Methods
5. Results
6. Discussion
7. Conclusions

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Introduction – tremor in Parkinson's disease

Tremor (commonly shake, tremble) is an unintentional muscular control deficit that results in cyclic movement deviations

In **Parkinson's disease** (PD) tremor (in rest) is one of the main symptoms – if not the most formative one

Tremor in PD is (most probably) caused by

- reduced **motor activity**
- (as a consequence of) reduced level of the neurotransmitter **dopamine**
- (due to) destruction of the **substancia nigra**

Functionally speaking, all tremor causing phenomena can be seen as **disturbances** of or **latencies in the neuronal regulation** of a muscular process

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Introduction – vocal tremor

- vocal tremor is an *unintentional* low-frequency **modulation of the vocal fold vibration**
- unlike other tremors (the acoustic representation of) vocal tremor channels into two components:
  - **frequency tremor**
  - **amplitude tremor**
- probably **all** of the neuronal **disturbances or latencies** (caused by caffeine, aging, disease, …) of voice production **are interweaved** in both tremor types

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Introduction – inconsistent literature results

But the effect of PD on vocal tremor is still not too clearly understood:

- Cnockaert et al. (2007) found:
  - vocal **tremor magnitude measures** depend rather sensitively on PD
  - tremor frequency does not relate to PD
- Nebel & Deuschl (2008) stated:
  - vocal tremor should **not** constitute an outstanding feature of PD
  - vocal tremor should be bound to **advanced stadia** of disease
  - **tremor frequencies around 9 Hz** could indicate PD
- Gillivan-Murphy (2013):
  - **amplitude tremor frequency** differs significantly between PD speakers (**below 5Hz**) and a control group (below 3 Hz)
  - PD speakers "were more likely to show **greater** auditory perceived [...] **magnitude[s]** of frequency and amplitude tremor […], however **without statistical significance**" (sic!)

L. Cnockaert et al. (2007): "Effect of Intensive Voice Therapy on Vocal Tremor for Parkinson Speakers", in *INTERSPEECH 2007 -- 8th Annual Conference of the International Speech Communication Association*, August 27-31.
A. Nebel & G. Deuschl (2008): "Dysarthrie und Dysphagie bei Morbus Parkinson." Stuttgart: Thieme.
P. Gillivan-Murphy (2013): "Voice tremor in Parkinson's disease (PD); Identification, characterisation and relationship with speech, voice, and disease variables." Dissertation, University of Newcastle.

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Data – the AHN corpus

used data are a subset of the Aix Hospital Neurology (AHN) corpus:
quasi-stationary parts (duration: 3s) of **sustained /a/-vowels** from 363 speakers

- 234 speakers (mean age = 66.66 a; SD = 9.81 a), diagnosed with Idiopathic Parkinsonism (PD), produced 416 vowels
- 182 (of those 234) PD speakers are recorded in off and on medication (L-DOPA) condition (364 vowels)
  - female speaker (id: 37), age: 78 a, off and on medication
  - male speaker (id: 24), age: 56 a, off and on medication
- 105 speakers (mean age = 62.29 a; SD = 10.85 a) are control speakers (CG) without any pathology; 105 vowels
  - female speaker (id: 284), age: 57 a
  - male speaker (id: 64), age: 65 a

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Acoustic measurement of vocal tremor with tremor.praat

tremor.praat extraction algorithm is

- based on **autocorrelation of** the **F_0 contour** and the **amplitude contour** and
- **corrected for the declination** that is naturally found in the F_0 contour and the amplitude contour
- **implemented in** the script language of the speech-processing program **PRAAT**
- tremor.praat (version 2.06) can be downloaded from http://brYkl.de/tremor2.06.zip

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Acoustic measurement: 6 measures

tremor.praat extracts **6 parameters** of vocal tremor

- 3 measures of **frequency tremor**
  - frequency tremor frequency (FTrF)
  - frequency tremor intensity index (FTrI)
  - frequency tremor power index (FTrP)
- 3 measures of **amplitude tremor**
  - amplitude tremor frequency (ATrF)
  - amplitude tremor intensity index (ATrI)
  - amplitude tremor power index (ATrP)

tremor intensity and tremor power indices are subsumed under the term **magnitude indices/measures**

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Acoustic measurement: tremor frequencies

tremor frequency definitions:

- FTrF is the **frequency** of the strongest low-frequency modulation of F_0
- ATrF is the **frequency** of the strongest low-frequency modulation of the amplitude (intensity).

computational principles (see (poster of) Brückl, 2012, for more detail):

- extract contours from sound
  - remove linear declinations (by subtraction of the linear regression estimates)
  - resample amplitude contour at constant rate (since in PRAAT's "Amplitude Tier" amplitude values are assumed to be in the center of their period)
- autocorrelate the contours
- "strength" of low-frequency modulation is determined via the contours' autocorrelation coefficients

Acoustic measurement: tremor intensity indices

tremor intensity definitions:

- FTrI is defined as the **intensity** of the strongest low-frequency modulation of F_0
- ATrI is defined as the **intensity** of the strongest low-frequency modulation of the sound's (intensity-per-period-) amplitude (A)

computational principles:

- normalize the (de-declined) contours by

$$relative\ F_0 = \frac{F_0 - \overline{F_0}}{\overline{F_0}} \qquad relative\ A = \frac{A - \overline{A}}{\overline{A}}$$

- the time marks of the contours' extrema are found with PRAAT's built-in function "To PointProcess (peaks)", once the tremor frequencies are known
- intensity indices are then determined by:

$$(F,A)TrI = \left(\frac{\sum_{i=1}^{m} |max_i|}{m} + \frac{\sum_{j=1}^{n} |min_j|}{n} \right) \div 2$$

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Acoustic measurement: tremor power indices

- FTrP and ATrP result from **weighting the intensity indices with** factors that are depending on **tremor frequencies**
- these factors are defined smaller for lower frequencies and therefore a lower power index would emerge if the **same tremor intensity** was found at a **lower tremor frequency**

$$FTrP = FTrI \cdot \frac{FTrF}{FTrF+1} \qquad ATrP = ATrI \cdot \frac{ATrF}{ATrF+1}$$

- power indices are thought to be **biologically and psychologically more significant for the concept "tremor magnitude"** than the known intensity indices, since the (perceived) effect of tremor events of the same intensity should be bigger, if they occur more often per time unit

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Acoustic measurement: examples

demonstration of the PRAAT script tremor.praat

id	parkinson	dopamin	gender	age	FTrF	FTrI	FTrP	ATrF	ATrI	ATrP
24	yes	no	M	55.85	2.50	2.24	1.601	5.69	6.119	5.205
24	yes	yes	M	55.85	1.70	1.48	0.934	11.37	3.821	3.512
37	yes	no	F	78.39	1.67	2.67	1.667	4.02	10.669	8.544
37	yes	yes	F	78.39						
64	no		M	64.54	1.83	0.81	0.524	1.65	7.382	4.594
284	no		F	57.17						

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Statistical methods

Problem: we aim to test the influence of PD on vocal tremor

1. main objective is to **compare** (means of) **tremor measures between** the group of **PD speakers** and the **CG**.
2. second aim is to **test tremor measures within PD speakers** in relation to the presence or absence of dopamine medication

Tests of the hypotheses:

H_0: There is **no difference** in tremor magnitude **between PD speakers and the control group** respectively **between the off and the on medication condition** or even lowered tremor values are found in the PD group respectively in off medication condition.

H_1: **Raised tremor magnitude values** are found **in PD speakers** respectively **in the off medication condition**.

(hypotheses for tremor frequencies are non-directional)

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Statistical methods

18 Analyses of co-variance (ANCOVAs):

- 6 (“independent samples”) analyses **comparing PD speakers off medication (PDoff) to the control group** (CG)
  - DV: (6) tremor measure(s)
  - (grouping) factors: pathology (observed and fixed), gender (observed and fixed)
  - covariate: speaker age
- 6 (“independent samples”) analyses **comparing PD speakers on medication (Pdon) to the CG**
  - DV: (6) tremor measure(s)
  - (grouping) factors: pathology (observed and fixed), gender (observed and fixed)
  - covariate: speaker age
- 6 (“paired samples”) analyses **comparing** within PD speakers **PDoff to PDon**
  - DV: (6) tremor measure(s)
  - (grouping) factor: gender (observed and fixed)
  - (within subjects) factor: medication (manipulated and fixed),
  - covariate: speaker age

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Statistical methods

- unbalanced designs: type 3 square sums
- only saturated models are used
- since all tremor measures are positively skewed (distributed): logarithm (ln) of measures is used in statistical (parametric) analyses

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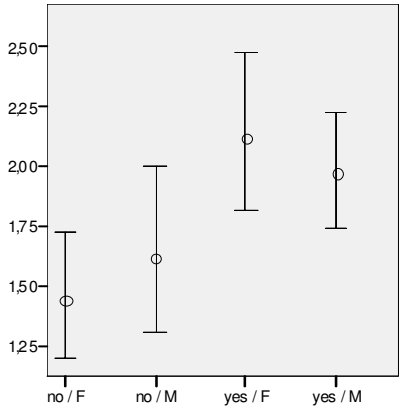
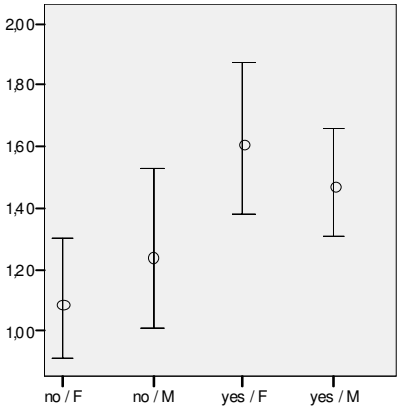
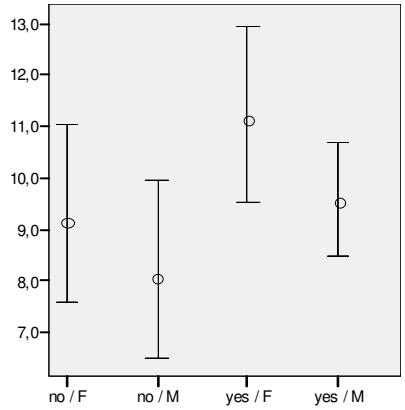
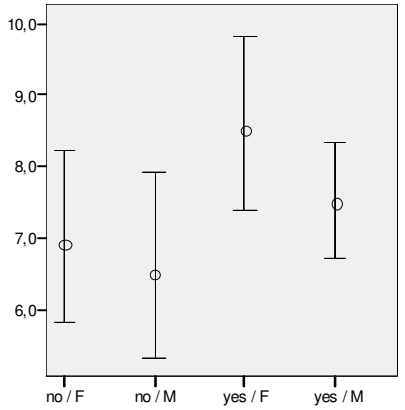
Results

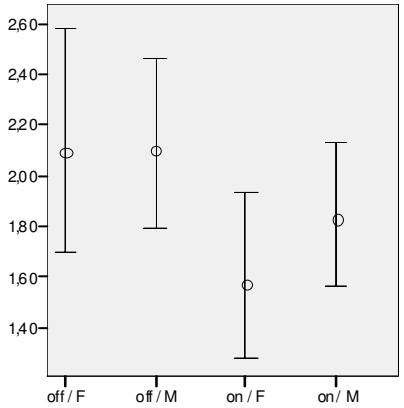
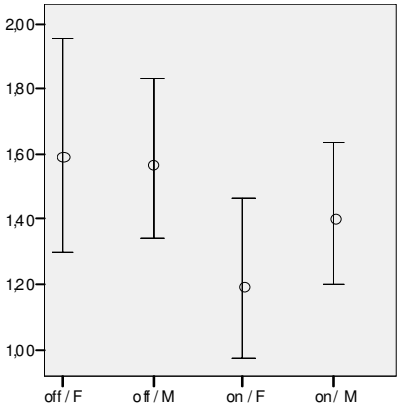
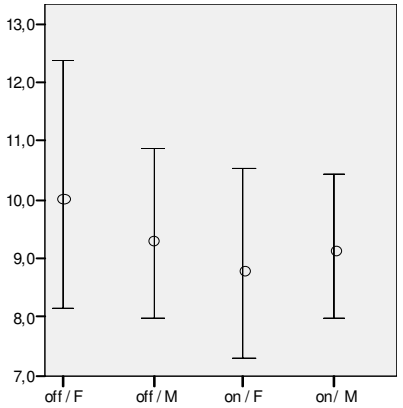
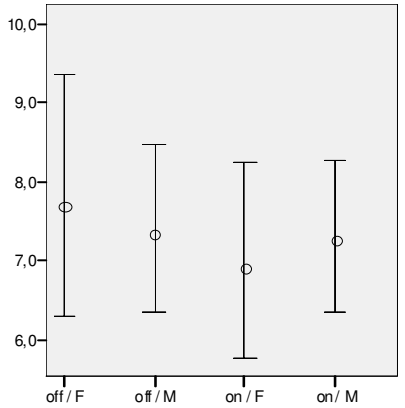
- **tremor frequencies** (FTrF and ATrF) **are not influenced by any factor** in all 18 analyses
- in the 6 comparison(s) of **PDon with the CG** only **speaker age varies** significantly with the tremor magnitude measures (no differences due to pathology)
- an **influence of gender** on the tremor (magnitude) measures may be seen as a trend (greater differences in female speakers) but does not reach significance level

Results – PDoff vs. CG

	FTrI	FTrP	ATrI	ATrP
EMMs & CIs PD, Gender				
PD	p = 0.05% η^2_P = 4.04%, η^2_G = 3.73%	p = 0.05% η^2_P = 3.94%, η^2_G = 3.61%	p = 2.0% η^2_P = 1.99%, η^2_G = 1.89%	p = 1.7% η^2_P = 2.12%, η^2_G = 2.02%
Age	p < 0.05% η^2_P = 7.34%, η^2_G = 7.04%	p < 0.05% η^2_P = 8.18%, η^2_G = 7.84%	p = 0.15% η^2_P = 4.18%, η^2_G = 4.05%	p = 0.1% η^2_P = 4.46%, η^2_G = 4.34%

→ tremor magnitude measures are significantly raised in PDoff

Results – PDoff vs. PDon

	FTrI	FTrP	ATrI	ATrP
EMMs & CIs Dopa, Gender				
Dopa	p = 0.1% η^2_P = 7.27%, η^2_G = 1.84%	p = 0.1% η^2_P = 7.33%, η^2_G = 1.68%	p = 12.75% η^2_P = 1.39%, η^2_G = 0.41%	p = 17.6% η^2_P = 0.93%, η^2_G = 0.26%
Age	p < 0.05% η^2_P = 14.11%, η^2_G = 10.66%	p < 0.05% η^2_P = 15.85%, η^2_G = 12.33%	p = 1.5% η^2_P = 4.97%, η^2_G = 3.5%	p = 1.3% η^2_P = 5.21%, η^2_G = 3.76%

→ frequency tremor magnitude measures are significantly raised in PDoff

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Discussion

based on our findings we have to

- **reject** the statements of Nebel & Deuschl (2008) as well as the results from Gillivan-Murphy (2013)
- **confirm** the findings of Cnockaert et al. (2007) as well as Gillivan-Murphy's speculations based on (insignificant results on) auditory perceived scales:

→ the **tremor magnitude measures** indeed **are observable features of PD** and

→ may serve to diagnose the disease even better and also in early stadia

- if they are combined with other dysphonia measures (see Tsanas et al., 2012)
- if the speaker age is controlled
- and if they are measured properly

A. Tsanas et al. (2012): "Novel speech signal processing algorithms for high-accuracy classification of Parkinson's disease", in *IEEE Transactions on Biomedical Engineering*

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Conclusions

- amplitude and frequency **tremor magnitudes** (intensity and power indices) **are increased in** sustained vowels that are produced by people that are diagnosed with **PD and off medication**.
- frequency tremor magnitudes also differ between the on and off medication conditions.

- Hence, tremor magnitude measures probably can be used -- together with other (vocal) measures and as long as the speakers' age is controlled -- to diagnose PD, maybe even in early stadia

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Questions?