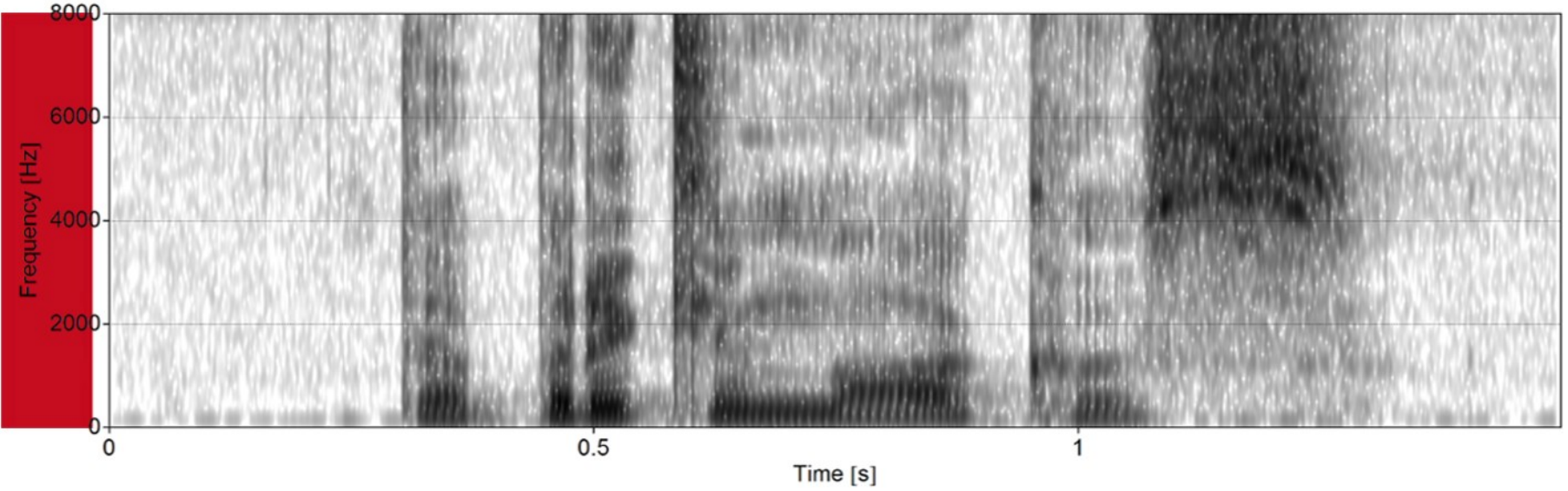

Acoustic Tremor Measurement: Comparing Two Systems

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Outline

1. Introduction
2. Methods
    a) Acoustic synthesis of the test sounds
    b) The tremor measurement systems
    c) Statistical methods
3. Results
4. Discussion
5. Conclusion

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Introduction – tremor as a symptom

The **ascertainment of tremor** (severity) bears a high potential to serve **for early diagnosis** of several, mostly **neuro-degenerative diseases** like

- Parkinson's,
- Alzheimer's,
- multiple sclerosis.

Tremor often is defined as **involuntary cyclic movement (deviation)** of the limbs, but…

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Introduction – vocal tremor

… 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.

→ The more than **80 <u>muscles</u>** of the vocal apparatus **may all show tremor** and thus

→ **vocal tremor** may have **many sources.**

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Introduction – vocal tremor

But once the **acoustic output** is investigated, all of these organic modulation sources combine to **only two types of tremor**: subsonic and quasi-cyclic modulations of the

- **frequency** and of the
- **amplitude**.

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Introduction – aim of the study

- 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.**

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Acoustic synthesis of the test sounds

a **completely synthetic** sustained vowel with **known tremor properties** is created by **formant synthesis**

- the glottal source signal is modelled with
  - 3s duration
  - 200Hz mean fundamental frequency

  according to [1] and then
- filtered by a time-invariant ‘female’-/a/-shaped filter function

this /a/-sound serves as the **carrier for the frequency and amplitude modulations**

[1] Rosenberg, A. E., “Effect of glottal pulse shape on the quality of natural vowels”, Journal of the Acoustical Society of America, 49, 583–590, 1971.

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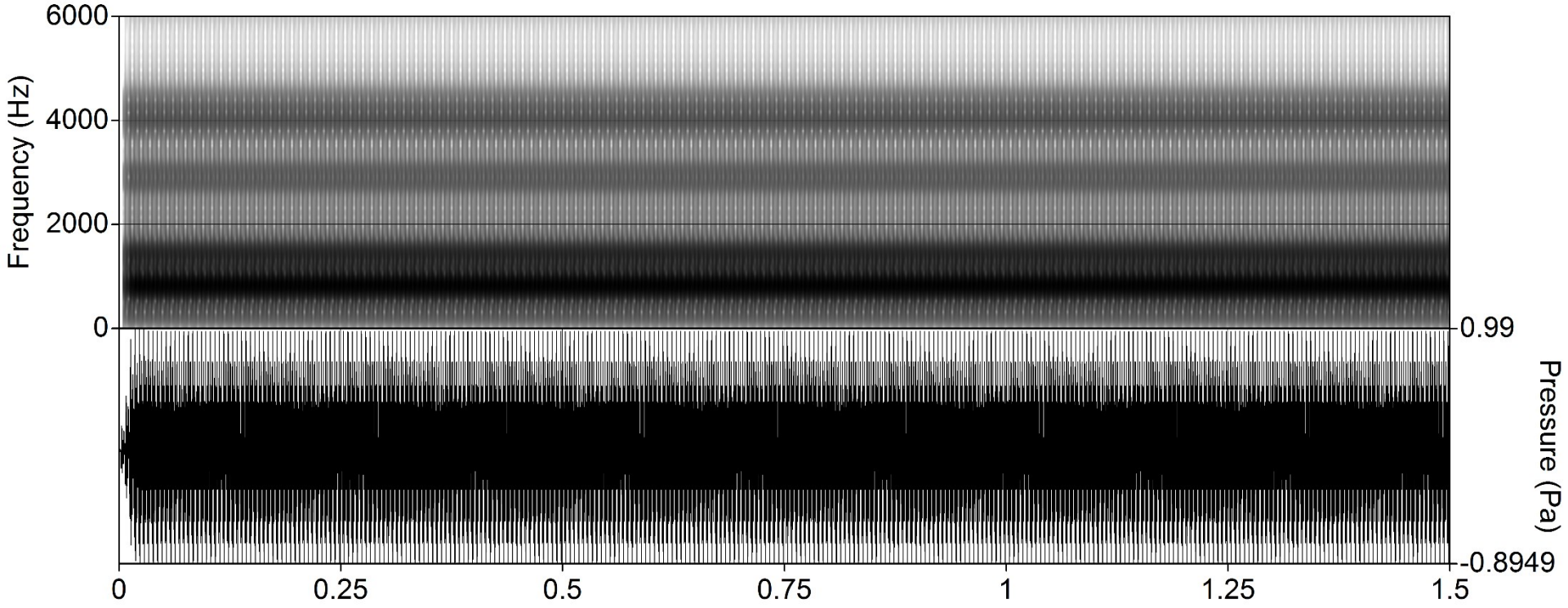
Acoustic synthesis – the modulation carrier



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Acoustic synthesis of the test sounds

- 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**:
  - frequency tremor frequency (FTrF[Hz])
  - amplitude tremor frequency (ATrF[Hz])
  - (relative) frequency tremor intensity (FTrI[%])
  - (relative) amplitude tremor intensity (ATrI[%])
- each argument is **varied in 4 equally spaced steps** across each range of naturally occurring values
- both a frequency and an intensity decline are synthesized

→ 4^6 = 4,096 test sounds

[2] Moulines, E., Charpentier, F., “Pitch-synchronous waveform processing techniques for text-to-speech synthesis using diphones”, Speech Communication, 9, 453–467, 1990.

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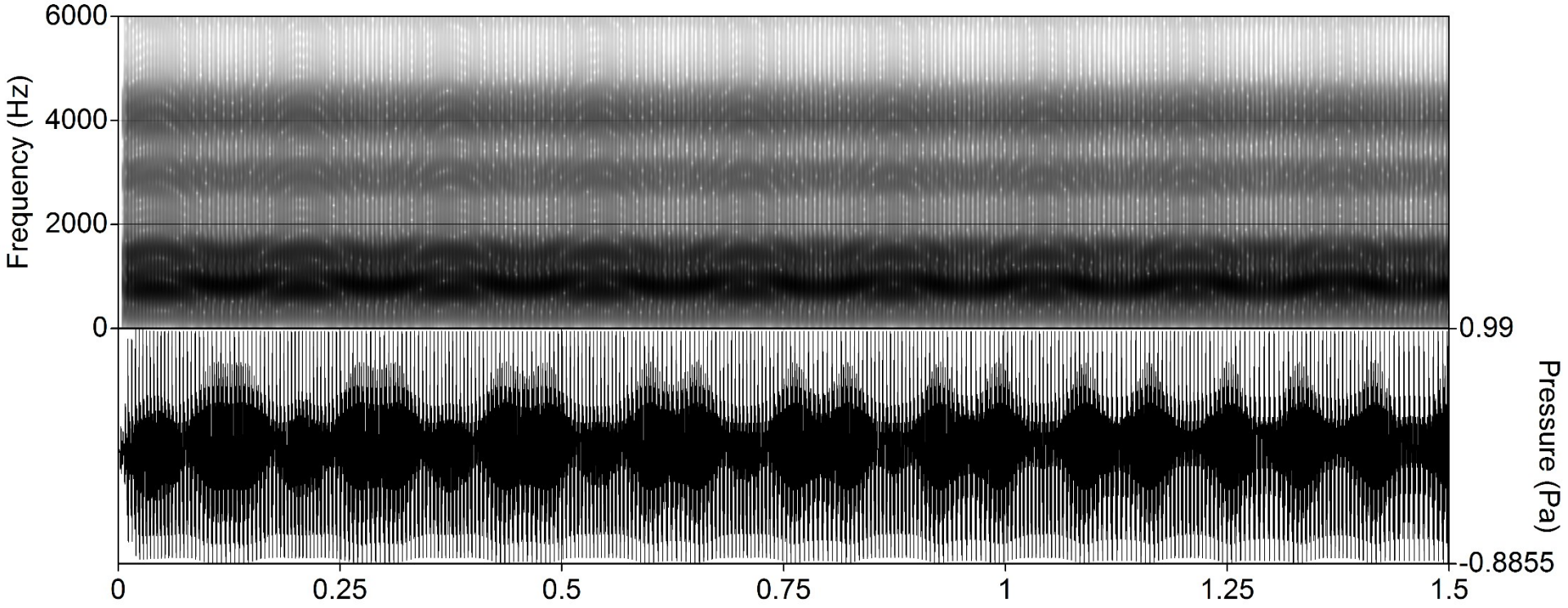
Acoustic synthesis – frequency modulation

$$F_0M(t) = F_{0,s} + FTrI \cdot \bar{F}_0 \cdot sin(FTrF \cdot 2\pi \cdot t) - decF \cdot t)$$



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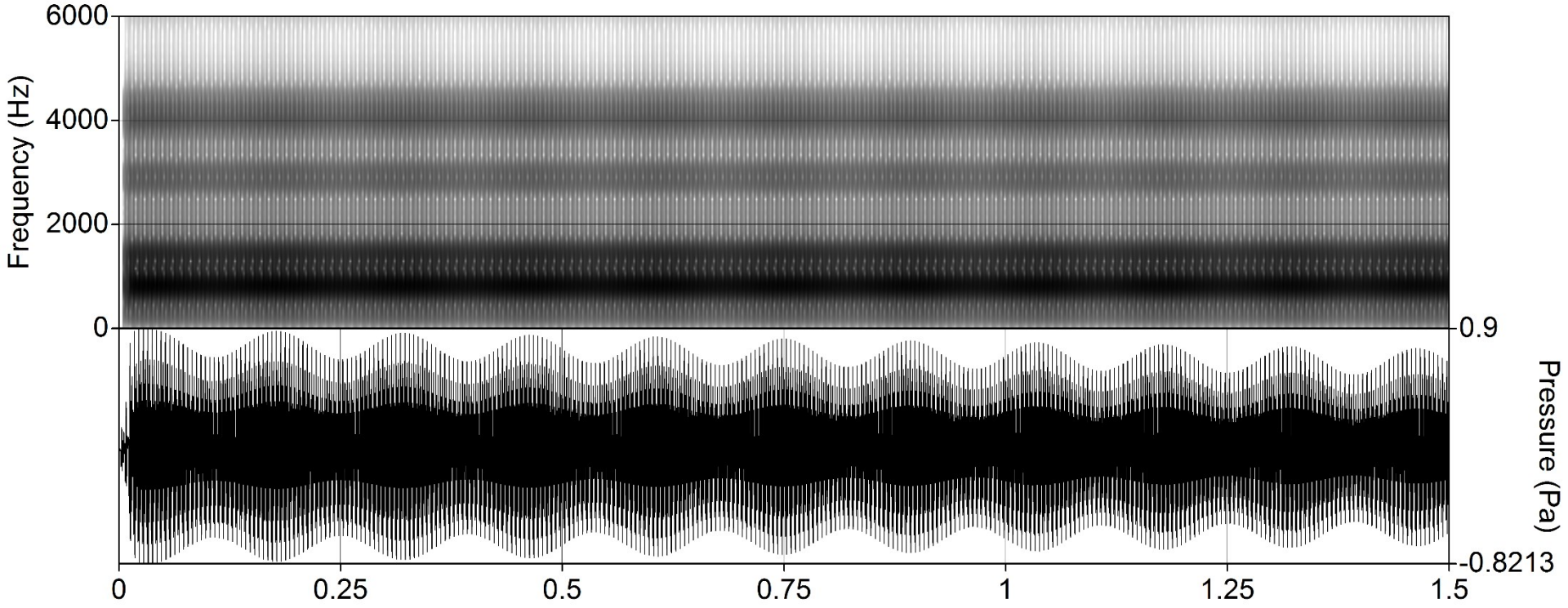
Acoustic synthesis – amplitude modulation

$$AM(t) = A_s + ATrI \cdot \bar{A} \cdot sin(ATrF \cdot 2\pi \cdot t) - decA \cdot t)$$



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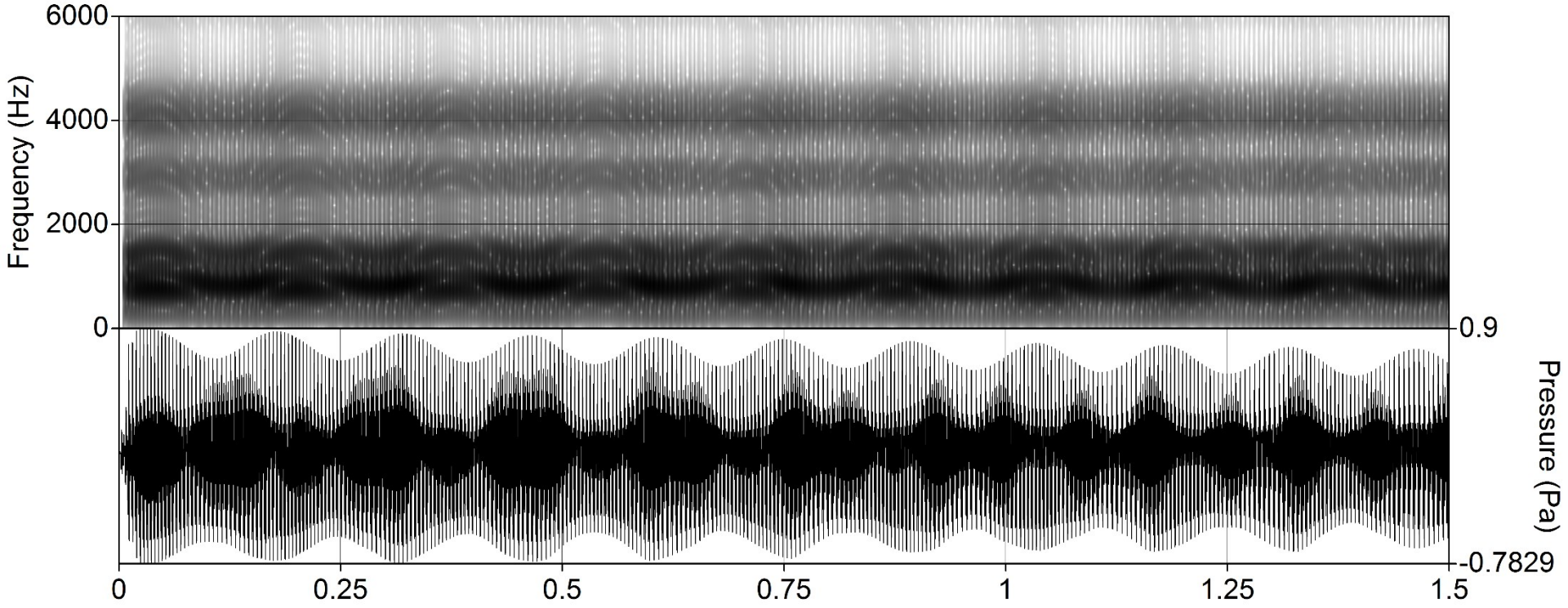
Acoustic synthesis – both modulations



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Measurement systems – MDVP's measures

MDVP [3] extracts **4 parameters** of vocal tremor:

- 2 measures of **frequency tremor**
  - frequency of the strongest low-frequency modulation of the fundamental frequency (Fftr [Hz])
  - mean magnitude of the strongest low-frequency modulation of the fundamental frequency (FTRI [%])

- 2 measures of **amplitude tremor**
  - frequency of the strongest low-frequency modulation of the amplitude (Fatr [Hz])
  - mean magnitude of the strongest low-frequency modulation of the amplitude (ATRI [%])

[3] Kay Elemetrics Corp. / PENTAX Medical, Multi-Dimensional Voice Program (MDVP), Model 5105 (Version 2.6.2) [Computer program], 1993/2003.

Measurement systems – TREMOR.PRAAT

TREMOR.PRAAT 3.01 extracts **14 parameters** of vocal tremor
4 out of these 14 meet the above definitions

- 2 measures of **frequency tremor**
  - frequency tremor frequency (FTrF)
  - frequency tremor intensity index (FTrI)
- 2 measures of **amplitude tremor**
  - amplitude tremor frequency (ATrF)
  - amplitude tremor intensity index (ATrI)

TREMOR.PRAAT is open-source software and implemented as a Praat [4] script

[4] P. Boersma, D. Weenink, Praat: doing phonetics by computer (Version 6.0.29) [Computer program], Uni-versity of Amsterdam

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Acoustic measurement of vocal tremor with tremor.praat

tremor.praat's algorithm is

- based on **autocorrelation of** the **F_0 contour** and the **amplitude contour** and
- **corrected for the declination** that is naturally found in both contours
- it is **implemented in** the script language of the speech-processing program **PRAAT**
- tremor.praat (version 3.01) can be downloaded from http://brYkl.de/tremor3.01.zip

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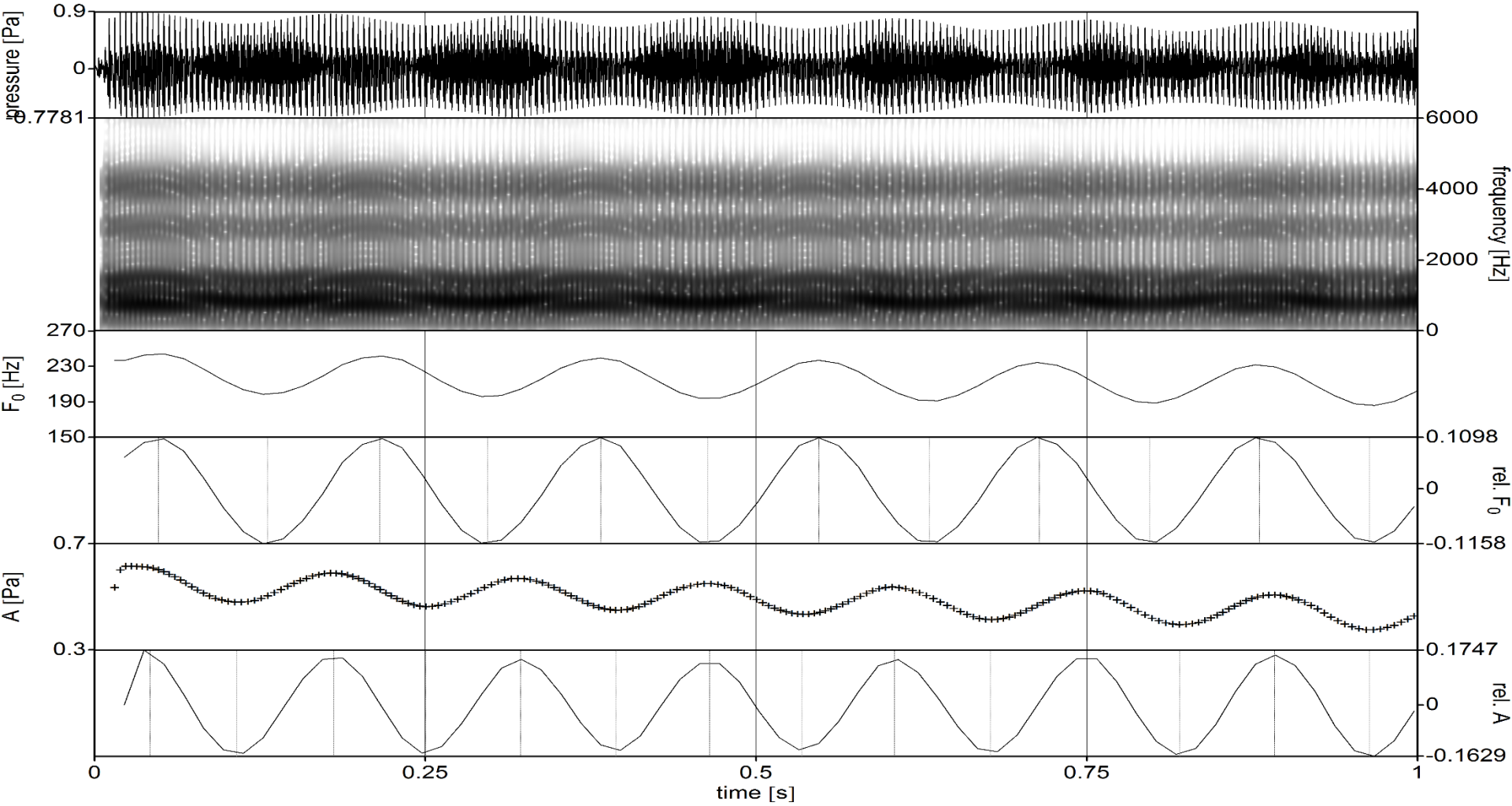

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Methods – extracting the tremor frequencies

- autocorrelate the (windowed) signal to estimate the F_0 –contour
- use PRAAT's "*To Amplitude*" function to extract amplitudes per period
- resample these time/duration-varying amplitudes at a constant time rate to derive an amplitude contour
- remove linear declinations of both contours by subtracting the linear regression estimates
- **autocorrelate the contours**
  - 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 (A).
  - [where "strength" is determined by the contours' autocorrelation coefficients]

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Methods – determining the tremor intensity indices

- normalize/relativize the (de-declined) contours by

$$rel.F_0(t) = \frac{F_0(t) - \bar{F}_0}{\bar{F}_0} \qquad rel.A(t) = \frac{A(t) - \bar{A}}{\bar{A}}$$

- 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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Comparison statistic – regressions' determination coefficients

8 **simple linear regressions** are computed
in order to assess the **dependence of** the 8 **measured values on** the 4 **synthesized values**

their determination coefficients (R^2) denote the **proportion of variance in the measured values that can be explained by the set values' variance**
→ they may serve as **coefficients of validity** of the 2 measurement instruments

99.99% **confidence intervals** (CIs) around these coefficients are calculated
in order to **indicate if** the populations of corresponding **coefficients differ from another**

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Results

MDVP **fails to extract**

- amplitude tremor measures in 513 cases and
- frequency tremor measures in 256 cases.

TREMOR.PRAAT **achieves to extract all measures** from all sounds, and…

TREMOR.PRAAT's measurement errors are highly significantly smaller, i.e. its measures are **highly significantly more valid** than those of the MDVP

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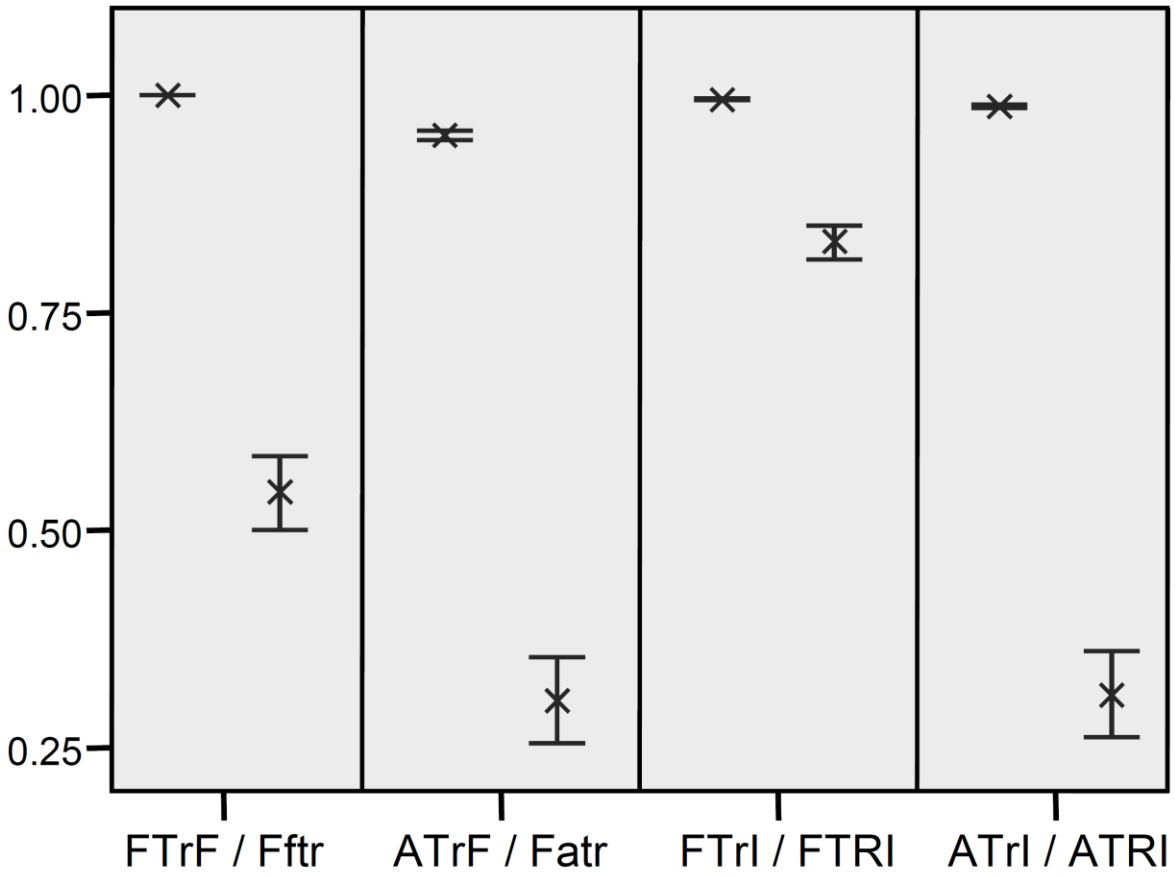
Results – R^2s and their CIs



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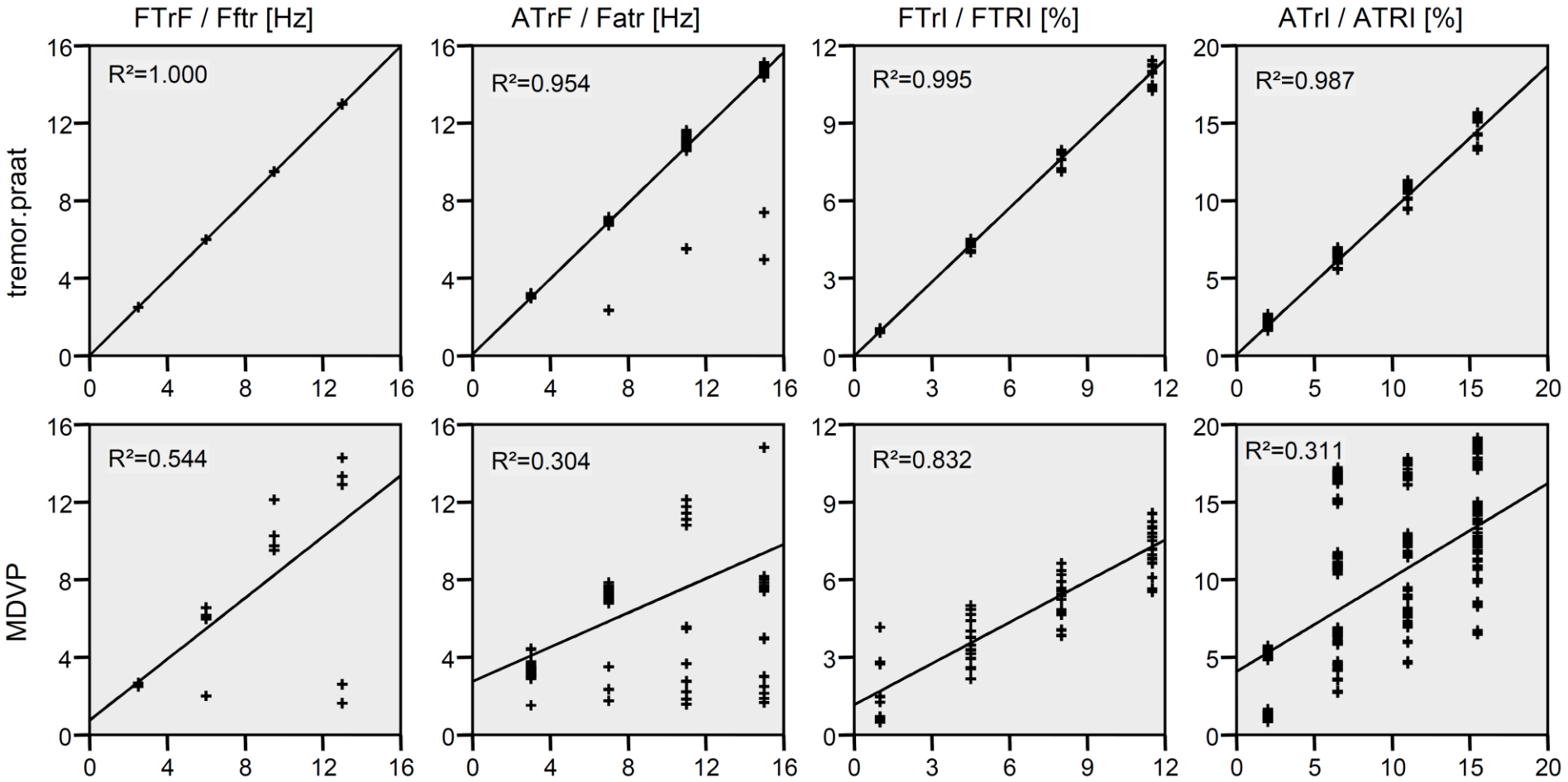
Results – scatterplots



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Discussion – errors of TREMOR.PRAAT

- the tremor intensity measures (FTrI and ATrI) exhibit **greater underestimations** at **greater synthetically set values**

- if ATrF gets extracted deficiently, then **exactly one or two octaves too low**
  → avoid by raising the *tremor octave cost*

since both error types are due to the (mandatory) quantization of the tremor contours
→ **all errors** in TREMOR.PRAAT's measurements may be reduced by **shortening the *analysis time step***

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Discussion – errors of the MDVP

- errors in the MDVP's extractions seem to be far **less systematic**
- sources **must remain unrevealed**, since the MDVP's algorithm is **proprietary** and thus **unknown**

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Conclusion

TREMOR.PRAAT is still under development, but…

it is **far more valid in measuring vocal tremor** than the standard program MDVP

→ use TREMOR.PRAAT for acoustic tremor measurement
→ re-measure formerly gained results based on the MDVP

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Questions

?

- send an email to: markus.brueckl@tu-berlin.de
- download tremor.praat: http://brYkl.de/tremor3.01.zip