Zen and art of vocal mechanics: Vocal Tremor

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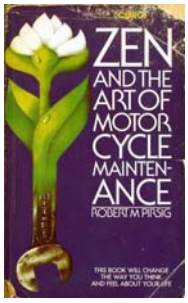
Disclosures

- **Financial:**
  - I am an affiliate instructor and receive royalties from MedBridge Inc related to my online courses on vocal tremor
- **Non-Financial:**
  - Research focus relevant to the presentation topic

Are tremor disorders diagnosed in the limbs the same as those affecting speech?

"You are never dedicated to something you have complete confidence in. No one is fanatically shouting that the sun is going to rise tomorrow."

-Robert M Pirsig



Roadmap of Talk

- What is tremor?
- What is vocal tremor (VT)?
  - General characteristics
  - Conceptual model
- Evaluation of Vocal Tremor
  - Auditory-Perceptual Patterns
  - Acoustic Patterns
  - Visual-Perceptual Patterns: Nasoendoscopy

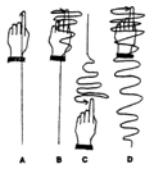
WHAT IS TREMOR?

- An involuntary rhythmic oscillation of opposing muscle groups.
- One of the most common neurologic movement disorders.

1. Louis (2016); Elble (2016); Crawford & Zimmerman (2011)

Tremor Classification

- **ACTION-INDUCED**
  - Purposeful movement
  - Postural
- **RESTING**
  - Supported from gravity



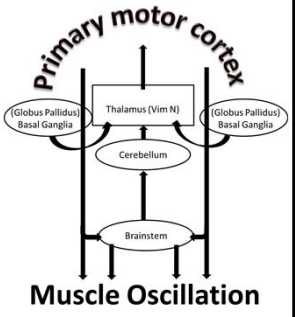
http://www.examiner.com/article/it-s-not-an-earthquake-its-just-parkinson-s-disease

http://gifsoup.com/view/1855096/pill-rolling-tremor.html

Hallett (2014); Weiss (2016)

Neural Pathways for Tremor

- Neural "Oscillators"
  - Primary motor cortex
  - Cerebellum
  - Basal Ganglia Globus Pallidus Pathways
- Tremor Patterns
  - Initiation of tremor
    - Basal ganglia pathways
  - Amplitude of tremor
    - Cerebello-thalamo-cortical network



Hallett (2014); Louis (2010); Raethjen & Deuschl, 2012)

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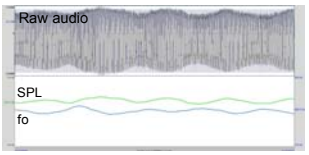
What is vocal tremor?

- Neurological voice disorder
- Involuntary rhythmic modulation of
  - PITCH (fo)
  - LOUDNESS (SPL)
- Can be a primary symptom, or associated with:
  - Essential Tremor
  - Dystonia
  - Parkinson Disease



(Brown & Simonson, 1963; Perez, Ramig, & Smith, 1996; Woodson, 2008; Woolraich, Marchis-Crisan, Redding, Khella, Mirza, 2010)

Vocal Tremor (VT)

- General characteristics
  - Best perceived during sustained phonation task (Brown & Simonson, 1963; Lederle, Barkmeier-Kraemer, & Finnegan, 2012)
  - Modulation of pitch and loudness can be further characterized (Gamboa et al, 1998; Dromey, Warrick, & Irish, 2002)
    - RATE (3-12 Hz)
    - MAGNITUDE (20-30%)
  - Significantly slower speaking rate than normal speakers (3 vs 5 syllables/s) (Lundy, Roy, Zxue, Casiano, & Jassir, 2004)
  - May improve (lessen) when drinking alcohol, depending on etiology (Sulica and Louis, 2010)

CONCEPTUAL MODEL

The acoustic consequence of tremor affecting structures within the speech mechanism resulting in an involuntary rhythmic modulation of the voice

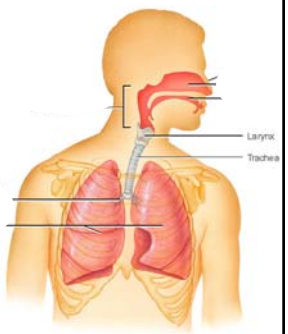
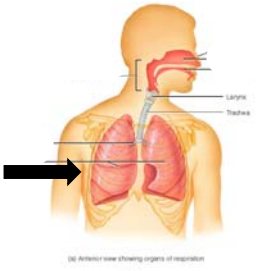


Figure taken from: Tortora, G.J. & Grabowski, S.R. (2003). The Respiratory System. In: Principles of Anatomy and Physiology Volume 4, The Maintenance and Continuity of the Human Body , 10th Edition (page 709).

HOW DO WE CONCEPTUALIZE VOCAL TREMOR PHYSIOLOGY?

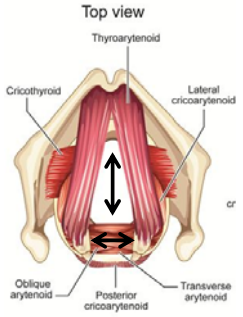
1. Respiratory System Oscillation
   - Subglottal pressure modulation
   - Ho: SPL modulation



(Simulations provided by Brad Story, University of Arizona)

HOW DO WE CONCEPTUALIZE VOCAL TREMOR PHYSIOLOGY?

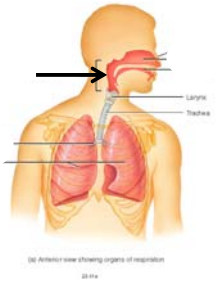
1. Larynx Oscillation
   - fo modulation (vocal fold length changes)
   - Ho: fo modulation
   - Glottal width modulation
   - Ho: SPL modulation (fo modeled as constant)



(Simulations provided by Brad Story, University of Arizona)

HOW DO WE CONCEPTUALIZE VOCAL TREMOR PHYSIOLOGY?

4. Vocal Tract
   - Pharyngeal diameter and length modulation
   - Ho: Formant modulation
     - F1 and F2 modulation associated with SPL modulations



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Principles Behind the Evaluation of Vocal Tremor

Guiding Principles for Detection and Evaluation of Vocal Tremor

- **Detection & Characteristics**
  - Important to compare sustained vs connected speech
  - Acoustic measures can be diagnostic
  - Laryngeal imaging confirms involved structures
- **Severity**
  - Compare between speech contexts
  - Ability to volitionally modify voicing duration

Auditory-Perceptual Evaluation

- Determine:
  - Presence/absence
  - Communication impact (i.e. severity)

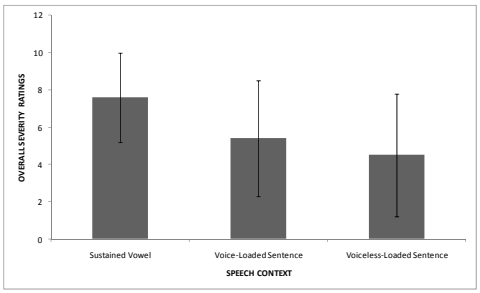
VOCAL TREMOR BY SPEECH CONTEXT

Sustained Phonation

vs.

Connected Speech

Vocal Tremor Severity by Speech Context

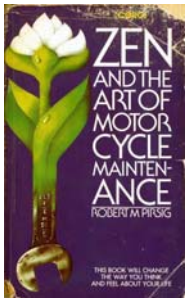


Lederle, A., Barkmeier-Kraemer, J., & Finnegan, E. (2012). Perception of vocal tremor during sustained phonation compared to sentence context. *Journal of Voice*, Sept;26(5):668.e1-9.

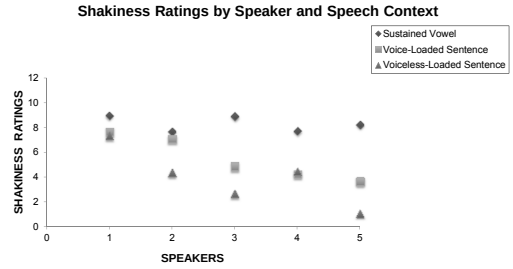
Sometimes, the devil is in the details

"An experiment is never a failure solely because it fails to achieve predicted results."

-Robert M Pirsig



Vocal Tremor Severity by Speech Context



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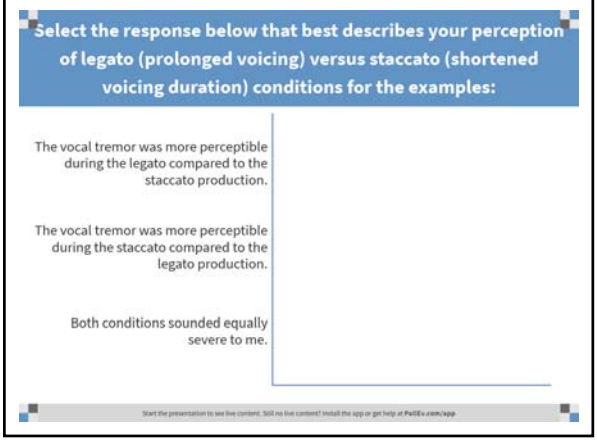
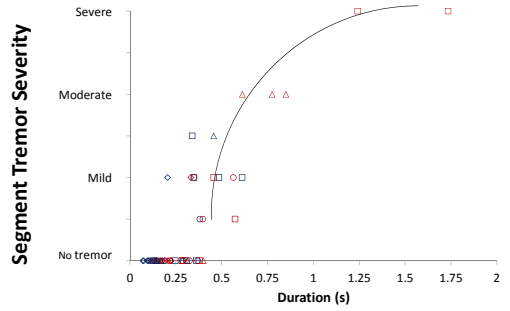
Vocal Tremor Severity by Voicing Duration

- Legato vs Staccato
  - Sample 1:
  - Sample 2

Twohig, A. & Finnegan, I. (2008). The effect of vowel duration on tremor severity for patients with vocal tremor. Honor' s Thesis, University of Iowa, Iowa City, IA.



Voicing durations under 500ms = normal or mildly severe vocal tremor



Twohig, A. & Finnegan, I. (2008). The effect of vowel duration on tremor severity for patients with vocal tremor. Honor's Thesis, University of Iowa, Iowa City, IA.

Vocal Tremor Evaluation Speech Tasks:

- **Sustained phonation using /a/ and /i/ (laryngeal muscle testing)**
  - Comfortable, High, Low Pitches (CT versus TA)
  - Comfortable + Loud (Interarytenoid, LCA)
  - Comfortable + Soft (PCA)
- **Connected Speech (severity judgments)**
  - Sentences with all-voiced speech sounds compared to
  - Sentences loaded with voiceless speech sounds
  - Conversation

Comparison of two cases

	Sustained Phonation	Connected Speech
Case 1		
Case 2		

What is your perception of vocal tremor severity for each during sustained phonation? Connected speech?

Select the response below that best describes your impression of vocal tremor severity for Case 1 and Case 2 during sustained phonation:

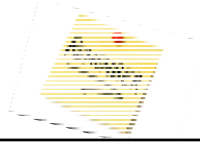
- Case 1 sounded more severe than Case 2.
- Case 2 sounded more severe than Case 1.
- Case 1 and Case 2 both sounded similar in severity of vocal tremor.

Select the response below that best describes your impression of the severity of vocal tremor during sentence reading for Case 1 compared to Case 2.

- Case 1 sounded more severe than Case 2.
- Case 2 sounded more severe than Case 1.
- Case 1 and Case 2 sounded similar in severity of vocal tremor.

TAKE HOME POINTS:
Auditory-Perceptual Evaluation of Vocal Tremor

- **DETECTION** = Sustained phonation
- **SEVERITY** = Connected speaking vs Sustained phonation
- **POTENTIAL FOR THERAPY**: Ability to reduce voicing duration ≤ 500 ms



ACOUSTIC PATTERNS CAN BE DIAGNOSTIC OF VOCAL TREMOR

Listener Perceptual Study by "Source"

Jessie Liu, Sarah Cook, Christine Bartelt, Ashley Thibeault, Emma Amble, & Ashley Stitt
Brad Story & Julie Barkmeier-Kraemer
(Manuscript in preparation)

Perceptual Threshold

- Lowest
  - Larynx (Adduction/abduction)
  - Larynx (Length change)
- In-between
  - Vocal tract
- Highest
  - Respiratory system

Acoustic Analysis

Jessie Liu, Sarah Cook, Christine Bartelt, Brad Story, & Julie Barkmeier-Kraemer

Respiratory	F0	Adductory	Vocal Tract

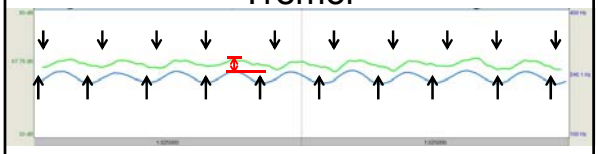
0%
.
.
.
.
.
.
.
.
.
100%

Acoustic analysis methods were superior to listener perception for detecting any of the sources of modulation studied.

Acoustic Measures

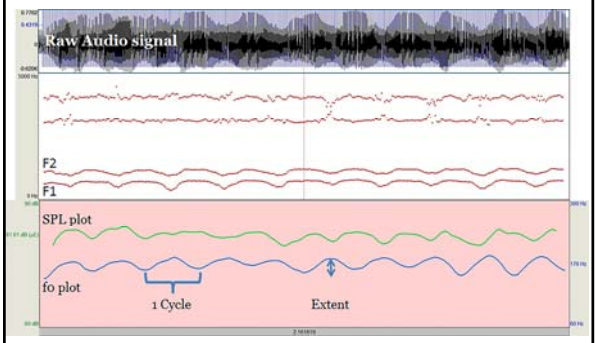
- Vocal Tremor characteristics:
  - Identify representative 1-2 second segment of acoustic modulation to measure:
    - **RATE**
    - **MAGNITUDE/EXTENT**
  - Compare across fo, SPL, F1 and F2 patterns
  - Connected Speech Sample
    - Articulation Rate

Acoustic Measures of Vocal Tremor



- **Rate** = cycles/second
- **Amplitude**
  - Measure the maximum and minimum value for each cycle of modulation
  - $(X_{max} - X_{min}) / (X_{max} + X_{min}) * 100 = X\%$
  - ***SPL amplitude in dB SPL is on a logarithmic scale***
    - Convert dB SPL measures to Pascals (linear)

Example of Acoustic Measures

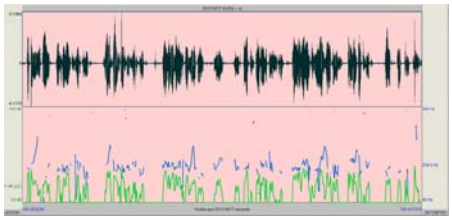


Example of Acoustic Measures

Modulation Cycle	F0 Max (Hz)	F0 Min (Hz)	F0 Mod Range	F0 Mod Mag (%)	Rel Int Max (dB)	Rel Int Min (dB)	Abs Pres Max (Pa)	Abs Pres Min (Pa)	Abs Pres Mod Range	Abs Pres Mod Mag (%)
1	255.00	228.00	27.0	5.6%	68.30	66.40	0.052	0.042	0.010	10.9%
2	251.00	230.00	21.0	4.4%	68.10	66.30	0.051	0.041	0.010	10.3%
3	255.00	229.00	26.0	5.4%	68.10	66.70	0.051	0.043	0.008	8.0%
4	254.00	228.00	26.0	5.4%	68.30	65.90	0.052	0.039	0.013	13.7%
5	254.00	228.00	26.0	5.4%	67.80	65.40	0.049	0.037	0.012	13.7%
6	257.00	226.00	31.0	6.4%	68.10	65.60	0.051	0.038	0.013	14.3%
7	253.00	230.00	23.0	4.8%	67.90	66.70	0.050	0.043	0.006	6.9%
8	257.00	227.00	30.0	6.2%	68.60	66.00	0.054	0.040	0.014	14.9%
9	254.00	227.00	27.0	5.6%	68.10	65.90	0.051	0.039	0.011	12.6%
AVG	**255.3**	**227.5**	**27.8**	**5.7%**	**68.2**	**66.1**	**0.029**	**0.023**	**0.006**	**6.9%**

fo	Rate = 4.5 Hz	Extent = 5.7%
SPL	Rate = 4.5 Hz	Extent = 6.9%
F1	Rate = 5 Hz	Coefficient of variation = .05%
F2	Rate = 5 Hz	Coefficient of variation = .05%

Speaking Rate (syllables/sec)



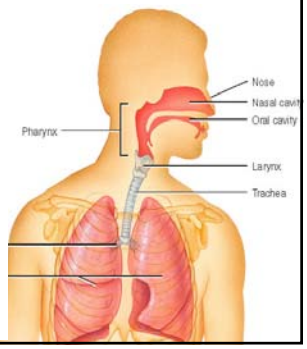
CAPE-V Sentences	Syllables	Start time (s)	End time (s)	Duration (s)	Rate (syll/s)
"The blue spot is on the key again."	9	105.6	108.7	3.1	2.9
"How hard did he hit him?"	6	109.5	111.5	2.0	3.0
"We were away a year ago."	8	112.4	114.5	2.1	3.8
"We eat eggs every Easter."	8	115.0	118.4	3.4	2.4
"My momma makes lemon muffins."	8	118.9	121.2	2.3	3.5
"Peter will keep at the peak."	7	121.7	126.3	4.6	1.5
	Average rate				**2.8**

Association of Formant Modulation with Vocal Tract Tremor

Ji A., Story B. Durbin-Johnson B, & Barkmeier-Kraemer, JM

Hypothesis:

- Vocal Tract Oscillation = Formant modulation (F1 and/or F2)
- N=12 subjects diagnosed with VT who underwent a standard clinical voice evaluation.
  - Acoustic Recordings
  - Endoscopic Evaluation



Association of Formant Modulation with Vocal Tract Tremor

Ji A., Story B. Durbin-Johnson B, & Barkmeier-Kraemer, JM

- **FINDINGS:**
  - Only those exhibiting oscillation of vocal tract structures showed formant modulation.
  - The **posterior pharyngeal wall** (p=0.04) and **base of tongue** (p=0.021) were found to be significant for F_1 and F_2 modulation, respectively.

Ji A, Story B, Durbin-Johnson B, Barkmeier-Kraemer J (2014). *Association of Formant Modulation with Oropharyngeal Vocal Tract Tremor*. Poster session presented at the Voice Foundation's 43rd Annual Symposium: Care of the Professional Voice, Philadelphia, PA.

Acoustic Measures can be Diagnostic of Vocal Tremor

- Acoustic recordings can detect vocal tremor when it is not perceptible
- Formant modulation is indicative of vocal tract structure involvement

NASOENDOSCOPIC IMAGING

- Diagnostic of tremor versus other movement disorders
- Influences treatment recommendations
  - Identify upper airway structures with tremor

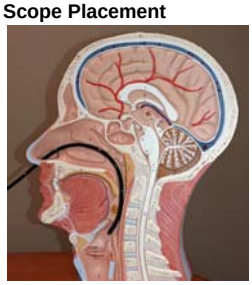
Nasoendoscopic Imaging

- **Videoendoscopy**
  - Evaluation of gross laryngeal and pharyngeal motion and structure (halogen light)
- **Videostroboscopy**
  - Evaluation of vocal fold vibratory characteristics and structure (xenon or LED light)

Advanced Technological Laryngeal Imaging

Flexible Scope

Scope Placement



Rigid Scope Placement

Laryngeal Imaging: Methods

- Light Source Differences
  - **Videoendoscopy**
    - Constant **halogen** light source
  - **Videostroboscopy**
    - **Xenon** or **LED** strobe light source

Nasoendoscopic Imaging Exam

- Overall laryngeal structure
- Vocal fold structure and symmetry
- Glottic configuration during vocal fold closure
- Vocal fold vibratory patterns
- Supraglottal activity

Recommend: Poburka, BJ. A New Stroboscopy Rating Form, *Journal of Voice,* 1999; 13(3):403-413.

NASOENDOSCOPIC IMAGING
Vocal Tremor Scoring System (Bove' et al, 2006)

- Rate the severity of tremor (using nasoendoscopy) in the
  - Supraglottis
  - True vocal folds (VF)
  - Base of tongue
  - Pharynx
  - Soft palate

  Severity rating scale:
  0 = none,
  1 = mild/intermittent,
  2 = moderate, or
  3 = severe
- Those with tremor severity ≥ within the true VFs responded best to Botox treatment
- Those with tremor outside the larynx did worse.

NASOENDOSCOPIC IMAGING: Visual-Perceptual Assessment

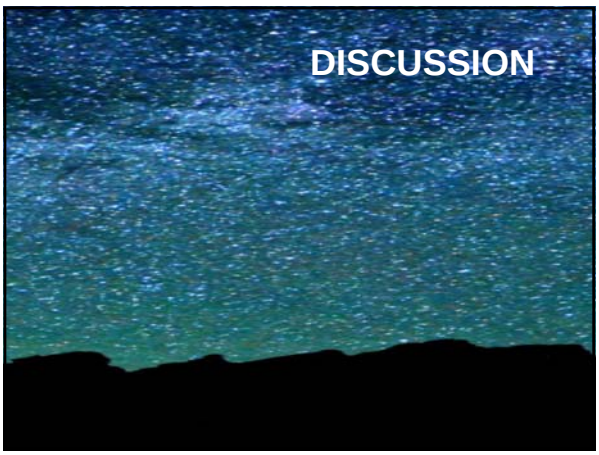
- Determine the prominent structure(s) contributing to the vocal tremor
  - **Laryngeal structures**
    - Easiest to perceptually detect
  - **Base of tongue and oropharynx**
    - Detected easily perceptually
    - Associated with modulation of F1 and F2
    - May undermine Botox® treatment benefit
  - **Respiratory system is sometimes involved**
    - Associated with slow rate (~3 Hz) SPL modulation

Vocal Tremor Case Example

Revisiting the Conceptual Model: Tremor Examples

Summary

- Vocal tremor is a neurological voice problem
  - action-induced tremor affecting speech structures
- The voice evaluation should elucidate the
  - Auditory-Perceptual and
  - Acoustic characteristics of vocal tremor across speech tasks
- Nasoendoscopic imaging of affected structures can:
  - Inform affected structures and musculature, and
  - Confirm tremor as the source of voicing patterns
- Voice evaluation findings for vocal tremor are critical to treatment planning



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