Measures to Evaluate the Effects of DBS on Speech Production

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PHYSIOLOGICAL

EMG
Oromotor nonverbal
Speech movement
Palatographic
Aerodynamic

ACOUSTIC

Segmental Measures
--Vowels
--Transitions
--Consonants
Rate Measures
Voice measures

PERCEPTUAL

Intelligibility Measures
--Closed set
--Trancription
--Scaling
--Comparison (ABX)
Error Analysis
Mayo Dimensions

Criteria for Candidate Speech Measures for the Evaluation of DBS Effects

- demonstrated sensitivity to dysarthria
- relevance to “functional” speech
- inference to underlying movement characteristics and/or neuropathology
- ease/simplicity of application

Physiological Measures

🗣 Oromotor, Nonverbal

easy; reliable?

sensitivity to dysarthria:

1) literature is devoid of reports showing meaningful relationships between oromotor nonverbal performance and speech production performance, *independent of the third variable influence of severity*

2) Theoretical justification is lacking, or worse (W. Ziegler [2003], *Aphasiology*, 17, 3-36; G. Weismer [2006], *Clinical Linguistics & Phonetics*, 20, 315-349)

Physiological Measures

- Speech movement

easy? (depends on structure being tracked)
reliable? (yes and no)

Sensitivity to dysarthria:

1) Preliminary data suggest that the more severe the speech problem (and possibly the disease) the more *reduced* the typical measures of speech movement (displacement, speed, acceleration)

2) measures may or may not distinguish speakers with dysarthria from control speakers, or speakers with dysarthria who have different diseases and presumably different underlying pathomechanisms

Physiological Measures

- Speech movement: Measures and forward predictions

$$\textit{Intelligibility} \approx (a)\,\color{blue}{PWS_{1\ldots n}} + (b)\,\textit{SEGMENTALS}_{1\ldots n} + (c)\,\textit{RES}$$

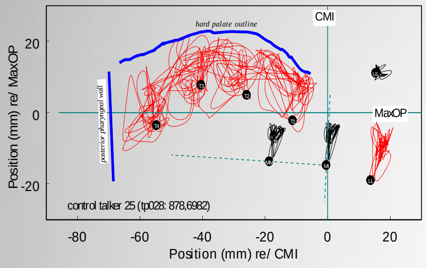


FIGURE 1

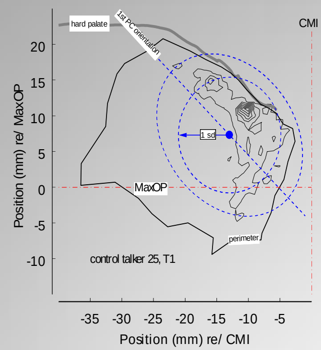
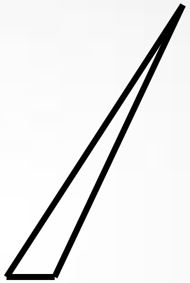

hard palate
1st PC orientation
CMI
20
15
10
5
0
-5
-10
Position (mm) re/ MaxOP
MaxOP
1 sd
perimeter
control talker 25, T1
-35
-30
-25
-20
-15
-10
-5
Position (mm) re/ CMI

FIGURE 2



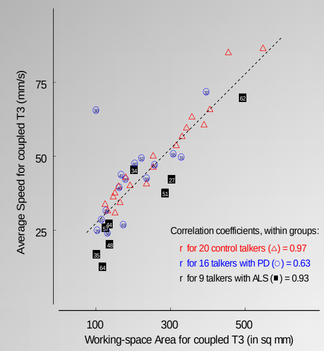
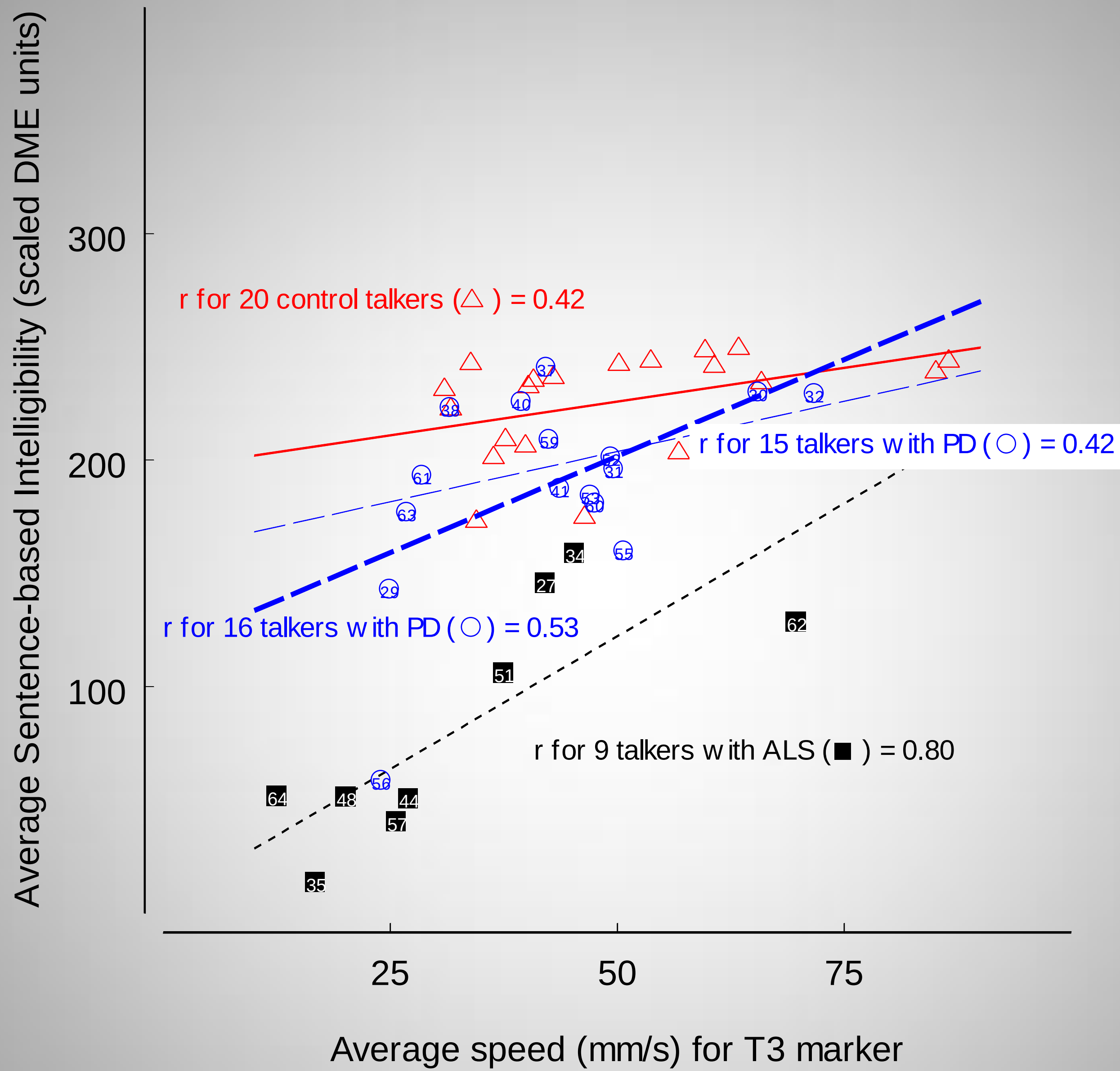
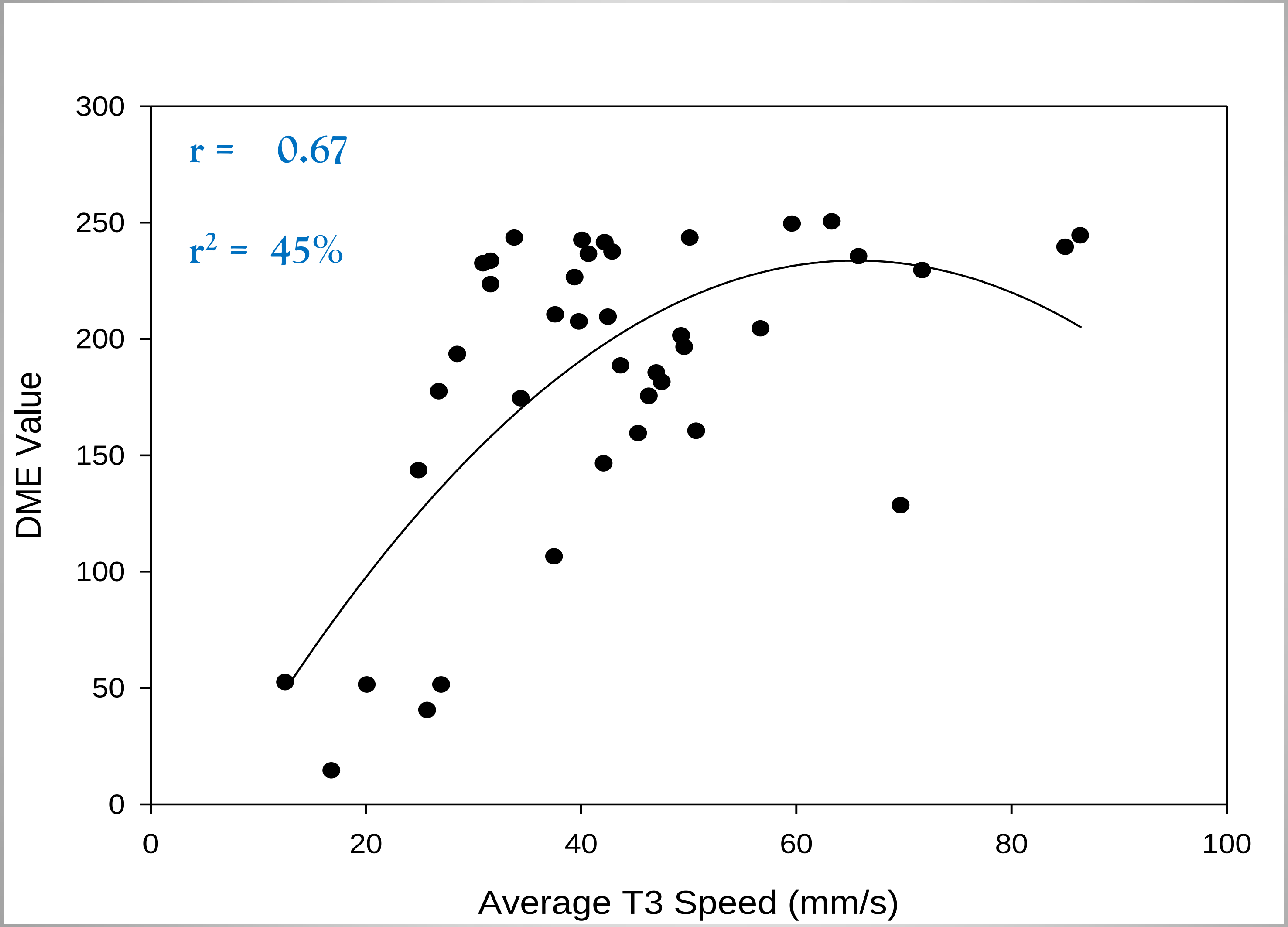

Average Speed for coupled T3 (mm/s)
75
50
25
100
300
500
Working-space Area for coupled T3 (in sq mm)
Correlation coefficients, within groups:
r for 20 control talkers (△) = 0.97
r for 16 talkers with PD (○) = 0.63
r for 9 talkers with ALS (■) = 0.93

FIGURE 7



Average Sentence-based Intelligibility (scaled DME units)
300
200
100
r for 20 control talkers (△) = 0.42
r for 15 talkers w ith PD (○) = 0.42
r for 16 talkers w ith PD (○) = 0.53
r for 9 talkers w ith ALS (■) = 0.80
25
50
75
Average speed (mm/s) for T3 marker

45 speakers, all (PD, ALS, Control) combined



Physiological Measures

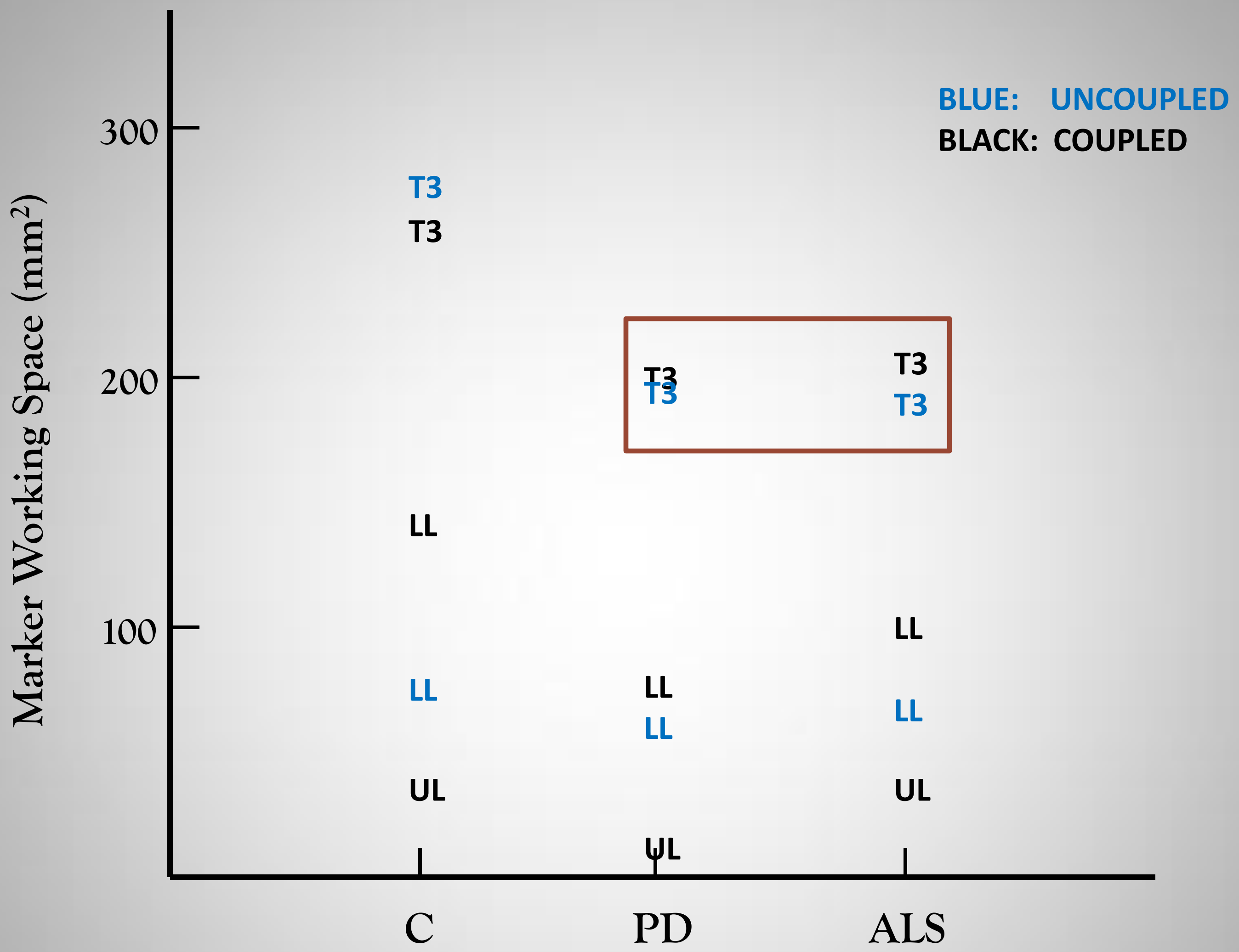
- Some tentative conclusions about speech movement

  - A general measure of articulatory working space, and the average speed derived from the movements that populate this space, seem to capture something about differences in phonetic "range" or "flexibility" between control speakers, and speakers with dysarthria

  - Areas of lingual working spaces (or the speeds derived from the movements) are correlated with estimates of speech intelligibility, more so in speakers with ALS than speakers with PD, but significantly so in both groups: a significant piece of the variance in the functional measure "intelligibility" seems to be captured by this gross estimate of articulatory behavior

Physiological Measures

- Additional findings on speech movement
  - *No* significant functions between lip (coupled or decoupled) and speech intelligibility were noted!
  - Lip + jaw areas/speeds do *not* predict lingual areas/speeds!
  - Inverse inferences to the tongue are highly desirable for evaluation of treatment effectiveness



BLUE: UNCOUPLED
BLACK: COUPLED
Marker Working Space (mm²)
300
200
100
T3
T3
LL
LL
UL
T3
T3
LL
LL
UL
T3
T3
LL
LL
UL
C
PD
ALS

Acoustic Measures

easy? *Yes*, a well-developed theory, body of experimental data, and explicit procedures have been worked out over the 60 or so years of the modern era of speech acoustic research.

too easy? *Maybe*.

reliable? *Yes*, especially when a speaker has a good source and very little chronic coupling between the oral and nasal cavities.

Acoustic Measures

Relevance to functional speech: HIGH

- For the majority of persons who perceive speech through the auditory channel, the speech acoustic signal is the data-bearing stream of information
- A series of analyses over the years has demonstrated explicit prediction of speech intelligibility scores via measures of segmental and "global" speech acoustics
- The speech acoustic signal is the bridge between speaker and listener, potentially allowing inverse inferences to underlying vocal tract behavior and forward inferences to speech intelligibility

Acoustic Measures

Sensitivity to dysarthria: VERY HIGH

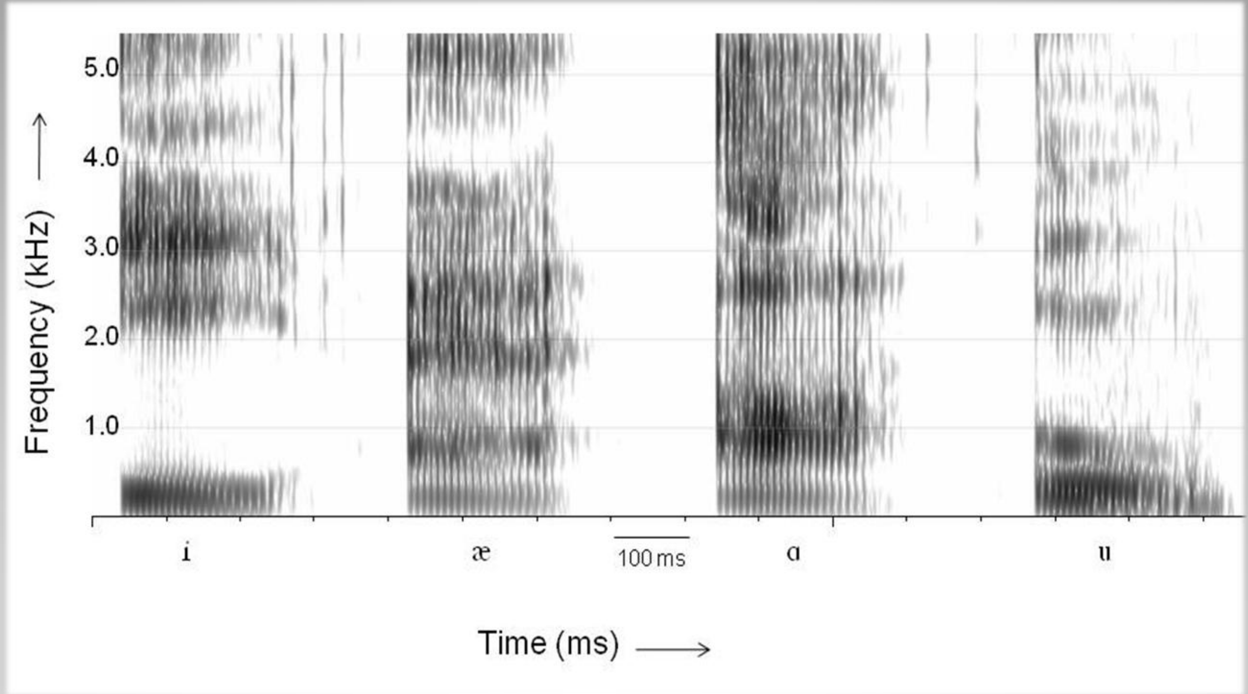
- Easy to show differences from “normal”
- Highly sensitive to variations in severity
- Not so sensitive (so far) to variation in dysarthria ***type***

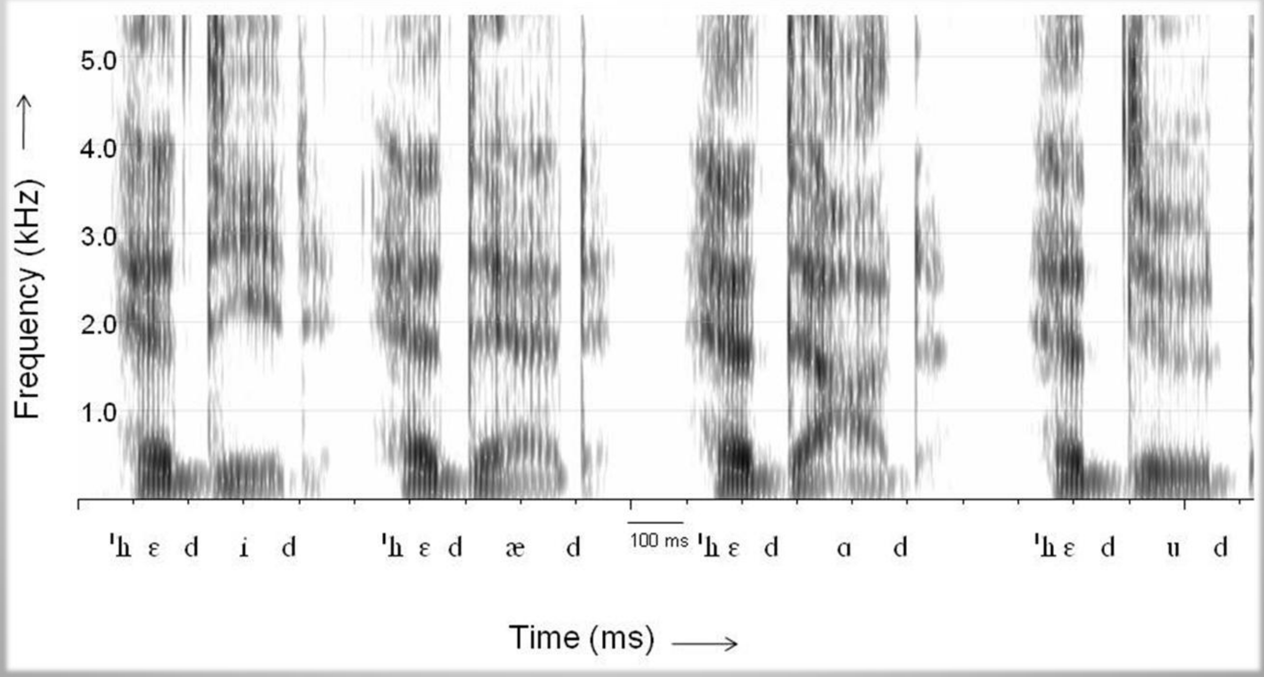
Which ***non-source*** acoustic measures are sensitive to dysarthria?

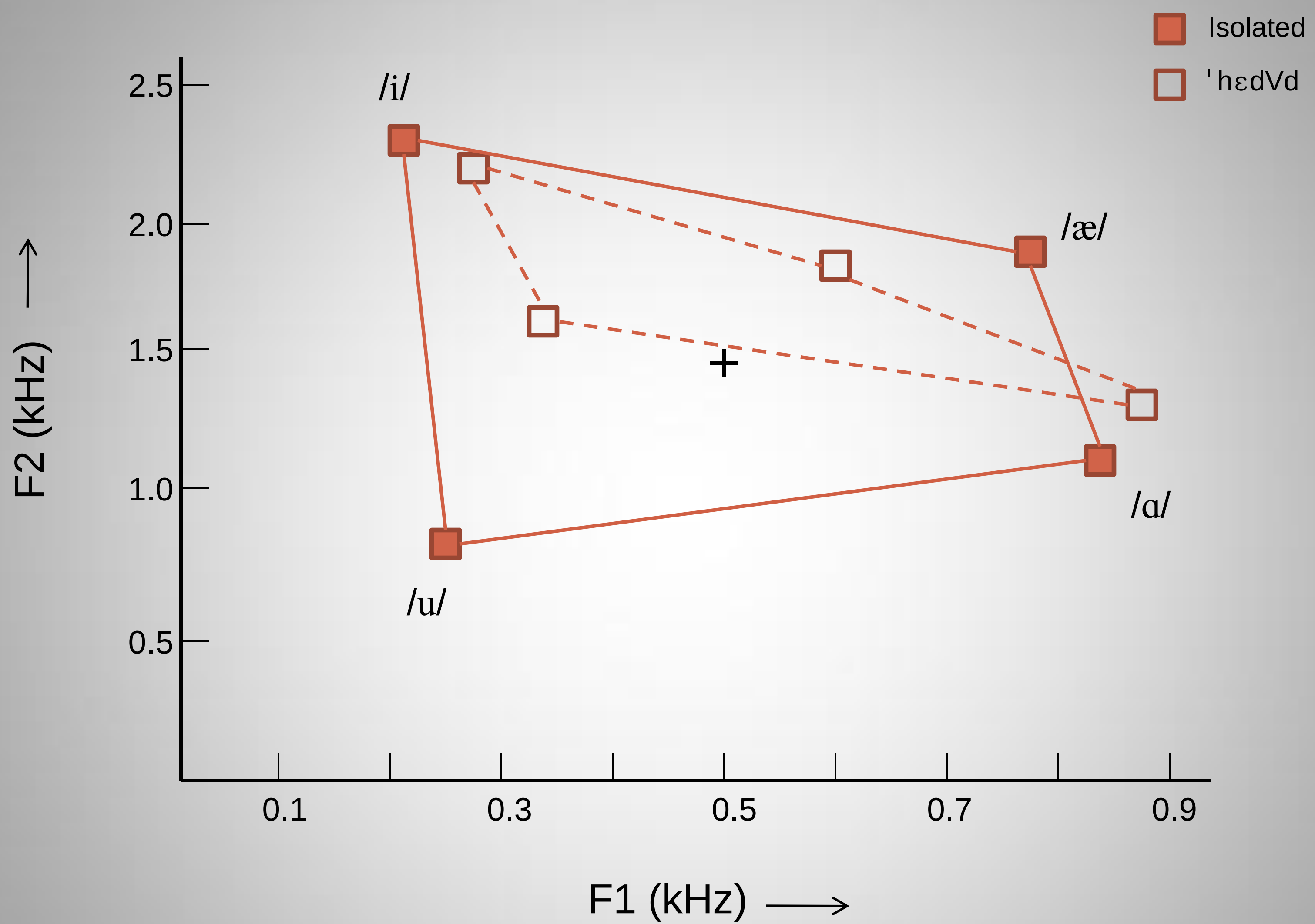
- Speaking rate and its segmental components
- VOT
- Formant frequencies and the derived vowel space
- Vocalic transition slopes (F2, most usually)
- Other contrasts

Acoustic Measures: Formant Frequencies and Vowel Space

- Fairly easy to measure but editing required!
- Several studies have shown the size of the acoustic vowel space to predict speech intelligibility scores, accounting for about 50-60% of the variance in the perceptual metric
- Size of acoustic vowel space seems more a global metric of severity of speech involvement, rather than an index of how vowels in particular contribute to speech intelligibility (like phonetic working space!)
- Speech tasks, contrast analysis, normalization

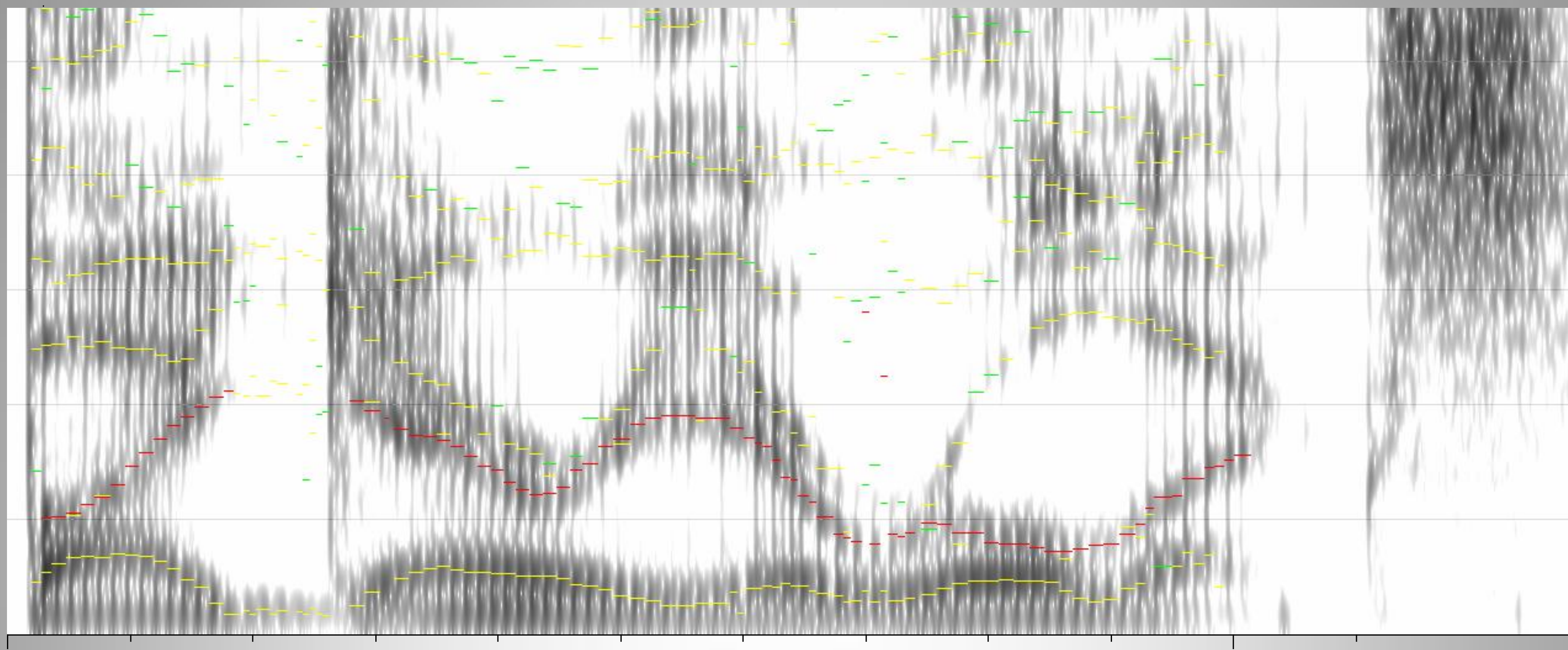

5.0
4.0
3.0
2.0
1.0
Frequency (kHz)
i
æ
100 ms
ɑ
u
Time (ms)


5.0
4.0
3.0
2.0
1.0
Frequency (kHz)
ˈh ɛ d i d
ˈh ɛ d æ d
100 ms
ˈh ɛ d ɑ d
ˈh ɛ d u d
Time (ms)


Isolated
ˈhɛdVd
/i/
/æ/
/ɑ/
/u/
2.5
2.0
1.5
1.0
0.5
F2 (kHz)
0.1
0.3
0.5
0.7
0.9
F1 (kHz)

Acoustic Measures: Formant Transitions

- Formant frequencies over time; tracks must be edited
- Transition rates—for any transition type—distinguish speakers with dysarthria from control speakers, regardless of type of dysarthria; transition rates also vary systematically with measures of speech intelligibility, for all dysarthria types [Kim, Weismer, Kent: *JSLHR*, in press]
- The inverse inference from transition slope to articulatory behavior is rate of change of vocal tract configuration, and probably articulatory speed
- High ease, reliability, sensitivity, and functional relevance, plus good inference to the underlying movement



b ɑɪ g æ r i ə r o l ɛ k s

“B uy G a r y a R o l e x”

Two General Conclusions (for now)

- *Speech* measures are likely to be the best for assessing the influence of DBS on speech production; 1) intelligibility measures may be best for the overall evaluation of speech severity, 2) F2 transition rates best for making correct inferences to lingual flexibility in the production of "quality" phonetic events

- The simple model:

$$\textit{Intelligibility} \approx (a)\,\textit{PWS}_{1\ldots n} + (b)\,\textit{SEGMENTALS}_{1\ldots n} + (c)\,\textit{RES}$$

should be pursued to determine the contribution of local speech movements (SEGMENTALS) and average speech loudness, prosody, F0 variation, and other factors (RES) to speech intelligibility changes resulting from DBS, or any other speech treatment

Merci from UW-Madison!