A Novel Index of Vowel Space:
Application to Clear Speech in Individuals with Parkinson Disease

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INTRODUCTION

Acoustic measures of articulatory behavior should sensitively track changes in articulatory motion related to speaking condition and dysarthria, and functionally relate to speech communication (e.g., perception of speech clarity) [1]. Although vowel space area (VSA) has been used to track condition-related articulatory changes, mixed findings have been observed in individuals with dysarthria [2-5]. Perceptual data may be used to triangulate the sensitivity of articulatory-acoustic measures relative to condition-related changes. There is evidence that traditional VSA may not adequately track articulatory changes related to perceptual rating of speech clarity in individuals with Parkinson disease [2,5].

In the current study, a novel acoustic measure that captures a representative distribution of working vowel space for connected speech was developed and tested.

Research Questions:

1. Does the novel Articulatory-Acoustic Vowel Space (AAVS) relate to listener perception of speech clarity?
2. Do the novel AAVS and the traditional VSA track clarity-related changes?
3. Does the novel Formant Trajectory Trace (FTT) show clarity-related changes in the speech of individuals with PD?

METHODS

Participants: A total of 13 young adults participated in the study (10 speakers, 3 listeners). Speakers were asked to read a set of phrases and a standard reading passage using clear and conversational speech. Listeners rated speech clarity of each of the 10 speakers using a 100mm visual analog scale of three target productions.

The Formant Trajectory Trace (FTT): The FTT is a plot of the complete vocalic formant trajectory history of a target production (Figure 1). The FTT is a collection of predicted formant values plotted in F1-F2 space for continuous speech. Formant values are sampled every millisecond for the entire utterance.

Articulatory-Acoustic Vowel Space (AAVS): The AAVS is the variability in F1-F2 space of the formant data for the entire utterance.

Traditional Vowel Space Area (VSA): VSA was calculated for a sentence containing all corner vowels using a traditional method.

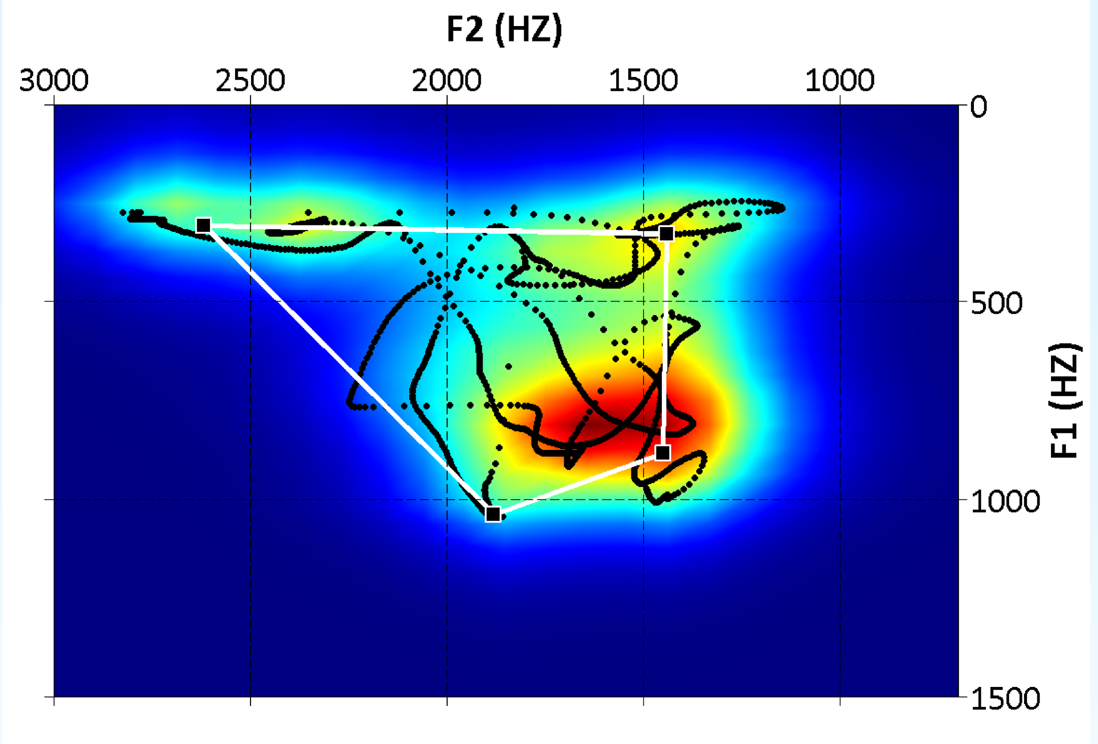

Figure 1: Display of the Formant Trajectory Trace (FTT) for a corner vowel-containing sentence "*She saw the stack of keys outside the blue box.*" produced by a female speaker using clear speech. Note the traditional vowel space area is also included.

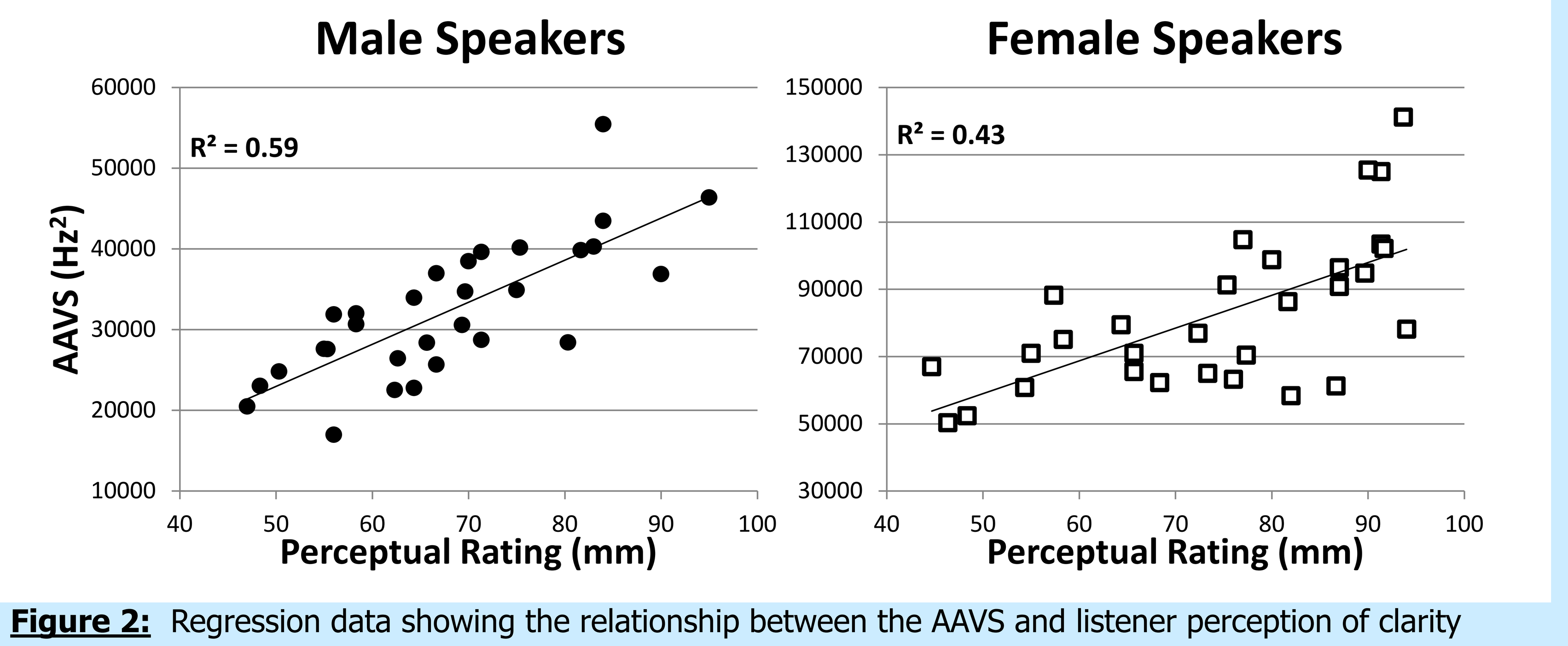

Figure 2: Regression data showing the relationship between the AAVS and listener perception of clarity

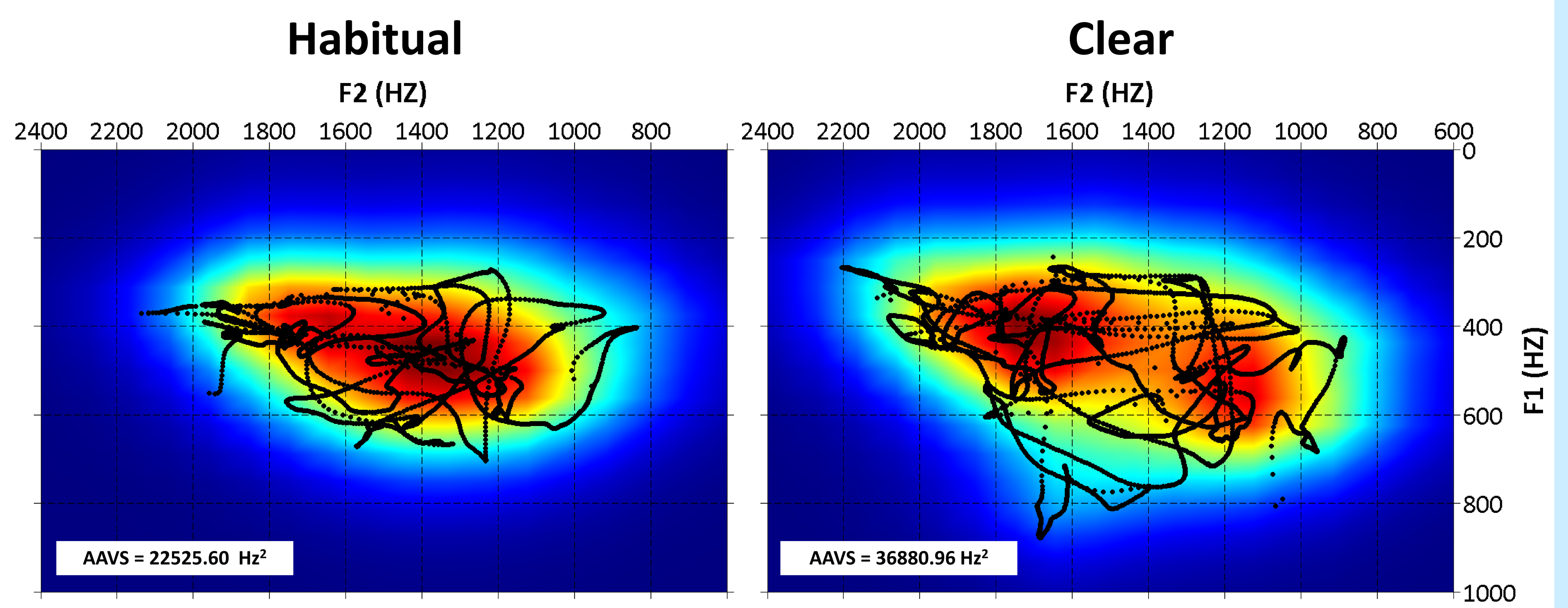

Figure 3: A FTT for the first sentence of the Rainbow Passage produced in a habitual (left) and clear (right) speaking condition by a male participant. Note: The centralized habitual-sample hotspot diverges into two decentralized clear-sample hotspots.

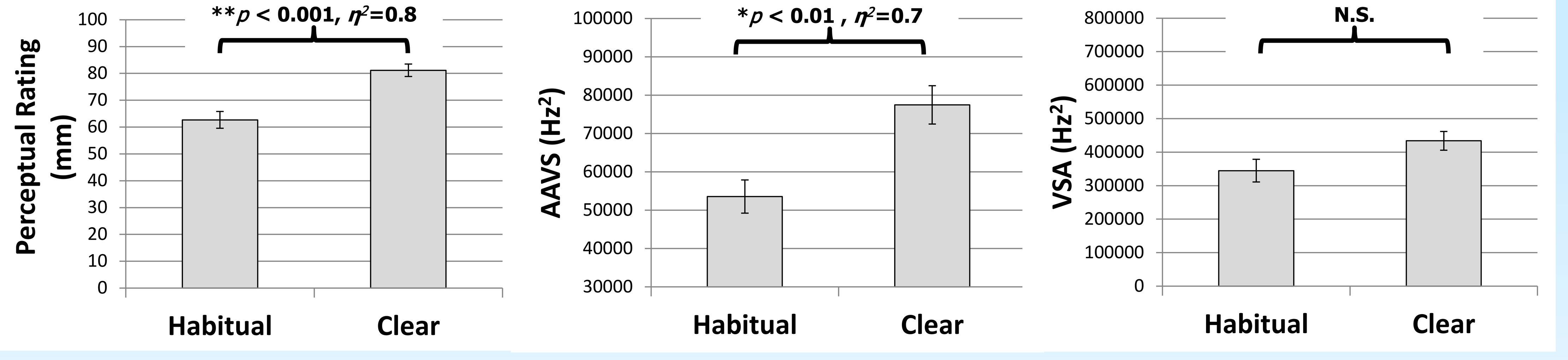

Figure 4: Estimated means (standard error) showing the main effects of speaking condition for the perceptual rating (left; 0 = unclear; 100 = very clear), the novel AAVS (middle), and the traditional VSA (right). The perceptual data indicate speakers increased speech clarity, confirming the AAVS adequately tracks changes in articulatory behavior.

RESULTS

AAVS Relates to Perception of Speech Clarity.
Regression analysis indicates the AAVS significantly predicted listener perception of clarity for male speakers [β = 0.766; p < 0.001], accounting for **58.9 percent** of the variance [R^2 = 0.59; F(1, 28) = 39.750; p < 0.001] as well as listener perception of clarity for female speakers [β = 0.654; p < 0.001], accounting for **42.7 percent** of the variance [R^2 = 0.43; F(1, 28) = 24.115; p < 0.001]. These data are shown in Figure 2.

AAVS tracked changes in speech clarity (& traditional VSA did not).
Repeated-measures MANOVA was used to examine the ability of the AAVS and VSA to track changes in speech clarity. Univariate results revealed a main effect of speaking condition for perceptual rating of clarity (p < 0.001; η^2= 0.8) and AAVS (p = 0.003; η^2= 0.7), but not VSA (p > 0.05).

A significant main effect of sex was observed for both AAVS (p < 0.001; η^2= 0.9) and VSA (p < 0.001; η^2= 0.9), but not for perceptual rating of clarity (p > 0.05). Figures 3 and 4 show data demonstrating the changes in clarity-related conditions.

APPLICATION TO PARKINSON DISEASE

As shown in Figure 5, the FTT analysis method seems to detect clarity-related changes in articulatory range of motion in individuals with PD. The AAVS increased from the habitual to clear condition for the male (13%) and the female (23%) speaker.

These preliminary results suggest that individuals with PD do increase articulatory range of motion when prompted to speak clearly. Traditional metrics of vowel space area may not adequately track these changes [e.g., 2,5].

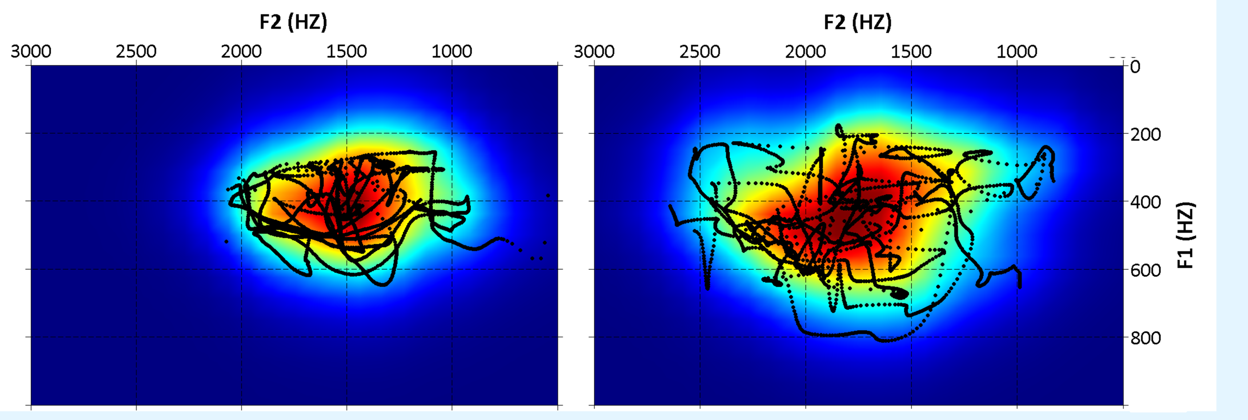

Figure 5: Habitual and Clear FTTs for the first sentence of the Rainbow Passage produced by a male speaker with PD (left = habitual; right = clear).

CONCLUSIONS

The novel AAVS strongly related to listener perception of speech clarity.

The novel AAVS more adequately sampled articulatory-acoustic behavior compared to traditional VSA. The AAVS may therefore allow for more robust tracking of clarity-related articulatory changes.

Preliminary results suggest that the AAVS is sensitive to speech clarity changes in individuals with PD, where traditional metrics of vowel space area have had variable success.

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