

ABSTRACT

Over the past decade there has been considerable interest in differences in the size and shape of vowel spaces across different ages and genders of speakers and across different regional dialects of English. Vowel spaces provide information about the distribution of vowels in the F1 by F2 plane in an individual speaker or group of speakers. Recent studies have investigated which vowels should be used to establish the spatial boundaries and what criteria should be used in drawing the boundaries. However, the weakness of all such approaches is that they do not take into account the number of vowels produced in different portions of the vowel space (the occurrence of a single vowel in a peripheral location is sufficient to enlarge the vowel space). This study proposes to expand and refine the concept of vowel space by creating vowel density maps across different regional dialects of American English. These maps represent a 3-dimensional overlay of relative vowel frequencies onto the F1 x F2 plane (the borders of which represent the vowel space). Dialectal differences will be described in terms of differences in the intersection of vowel space areas and differences in vowel density within different portions of the intersected spaces.

Introduction

What is the "vowel space area"?

The size (area) of the vowel space is usually used to characterize the nature of a speaker's (or a dialect's) vowel structure. The coordinated tongue and jaw movements are reflected in the formant pattern, which is the basis for measurement of the vowel space area. The vowel space area (VSA) is often determined for English speakers on the basis of the midpoint formant frequencies of the four "corner" vowels [i u a ɔ]. Measured in this way, systematic variation in the VSA was found as a function of speaking styles (Bradlow *et al.* 1996), speech disorders (Liu *et al.* 2005) and child development patterns (Vorperian & Kent 2007).

How to determine the vowel space area?

VSA is a problematic measure for several reasons:

- The size of the VSA depends critically upon the choice of vowels used to construct the borders of the vowel space, which eliminates a number of vowels which fall outside this circumscribed area.
- One can expand the VSA by including more vowels (and/or formant measurement points other than the midpoint), but then comes the question of how to determine the boundaries on the basis of these points (being more liberal or more conservative in the approach).
- No matter what approach is taken in determining the boundaries of the vowel space, the VSA can be adversely affected by the occurrence of just one outlier.

The effects of dialect on the vowel space area

We explore four approaches to determining the boundaries of the vowel space on the basis of production data from three regional varieties of American English spoken in Central Ohio, Southeastern Wisconsin and Western North Carolina.

Speech materials, speakers and procedures

- 14 American English vowels /i, ɪ, e, ɛ, æ, a, ɔ, o, u, ʊ, ɜ, ɔɪ, aɪ, aʊ/ were produced in h_d context in citation form using the prompts: *heed, hid, heyd, head, had, hod, hawed, hoed, who'd, hood, heard, hoyd, hide, howed.*
- 36 male speakers, 12 from each dialect, who were born, raised and spent most of their lives in their respective dialect regions. They ranged in age from 50 to 65 years.
- Each speaker produced three repetitions of each token for a total of 1512 tokens.
- A custom MATLAB program was used to control the experiment and the recordings.
- Acoustic analysis included sampling formant frequencies (F1 and F2) at five equidistant time points in a vowel (20-35-50-65-80%).

The boundary problem

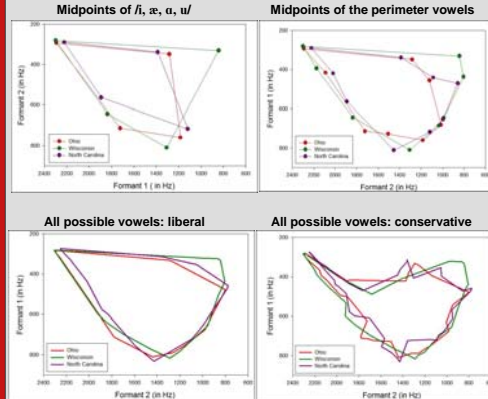


Figure 1. Different approaches to drawing the boundaries to determine the size of the vowel space in three dialects: Midpoints of the four corner vowels (upper left), midpoints of all perimeter vowels (upper right), all possible measurement points for all possible vowels using a liberal approach (lower left) and a conservative approach (lower right).

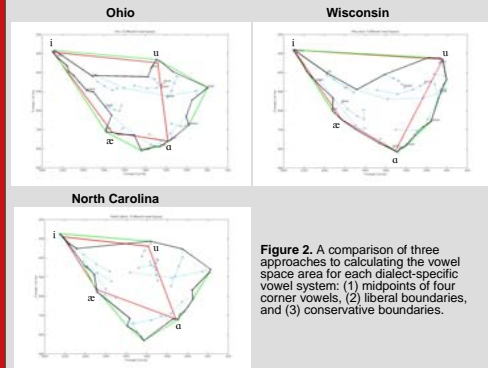


Figure 2. A comparison of three approaches to calculating the vowel space area for each dialect-specific vowel system: (1) midpoints of four corner vowels, (2) liberal boundaries, and (3) conservative boundaries.

| Dialect/State | Corner midpoints | Midpoints all vowels | Liberal all vowels | Conservative all vowels |
|----------------|------------------|----------------------|--------------------|-------------------------|
| Ohio | 0.315 | 0.379 | 0.497 | 0.378 |
| Wisconsin | 0.423 | 0.493 | 0.548 | 0.399 |
| North Carolina | 0.231 | 0.392 | 0.483 | 0.380 |

The calculated vowel space areas (in square kHz) differ significantly as a function of the approach taken to drawing their boundaries.

Vowel density graphs

The problem with all approaches to vowel space areas is that they fail to illustrate just where the vowels tend to fall, and which locations are most "heavily utilized." To better characterize vowel space utilization, we have created "vowel density graphs."

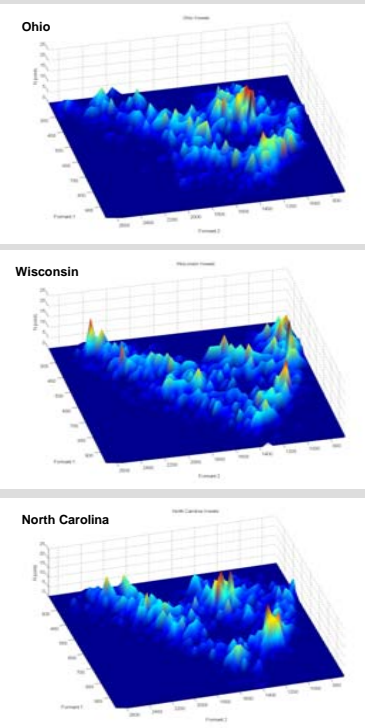


Figure 4. Vowel density graphs for each dialect.

The vowel density graphs show the number of vowel measurement points in the F1 x F2 plane. The graph represents a 40-point F1 axis (20-Hz cells, ranging from 204 Hz to 972 Hz) by 50-point F2 axis (41-Hz cells, ranging from 678 Hz to 2622 Hz). The graphs show the relative density of all vowel measurements (taken at five time points in each vowel) in the F1 x F2 vowel space. The color values are interpolated using Matlab.

Density comparisons

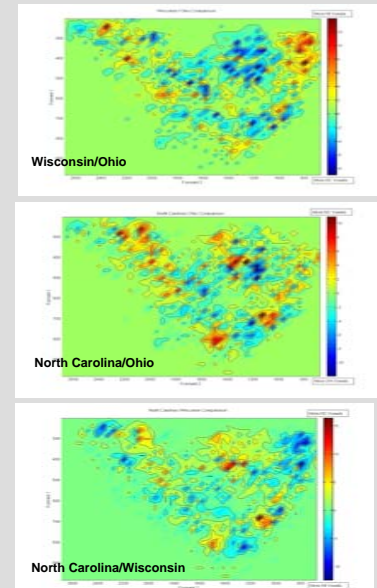


Figure 5. Vowel comparison graphs

The vowel comparison graphs (number of vowel measurement points in the 40 x 50 cell F1 x F2 in one dialect minus the number vowels in the other dialect) show differences in vowel density between one dialect and another. These graphs indicate relative differences in vowel space utilization between two dialects. These are differences that the vowel space boundaries cannot capture.

The vowel density approach explicates the differences in utilizing the regions in the vowel space by different dialects. Focusing on which areas are most and least utilized, vowel density graphs provide a better characterization of the vowel space actually used. This eliminates the problem of artificially expanding the working vowel space area by drawing boundaries on the basis of the appearance of just one exemplar.

REFERENCES

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