INTRODUCTION
Down syndrome (DS), the most common genetic disorder, is caused by the presence of an extra copy of chromosome 21. About 1 in 700 infants are born with Down syndrome or trisomy 21. Speech difficulties affecting speech intelligibility or speech clarity are common in individuals with DS, for a recent review of disorders of voice, voice sound, fluency and intelligibility in DS, see Kent and Vorperian.

Acoustic studies may help to understand the reduced intelligibility in DS and to identify the acoustic and motor factors contributing to the speech disorder. This study focuses on the area of the vowel quadrilateral in the F1-F2 plane. Reductions of quadrilateral area have been linked to reduced intelligibility in several speech disorders.

The purpose of this study is to compare the vowel acoustic spaces of speakers with DS and speakers who are healthy and typically developing (TD). Vowel spaces are analyzed as graphic displays of the F1-F2 vowel quadrilaterals for individual participants. Additional data are reported for two measures: Vowel Articulation Index (VAI) and Vowels and Articulatory Functional Ratio (VFR).

We hypothesized that speakers with DS will have a reduced size of the acoustic vowel quadrilateral compared to TD speakers. Also, that speakers with DS will exhibit atypical geometries of the vowel quadrilateral, particularly in the low-vowel region (i.e., a/i/).

BACKGROUND
Vowel formant frequencies in DS have been reported in several studies, but the results are not in complete agreement. Mouro et al. reported a smaller ratio of the F2 frequencies for the vowels /i/ and /u/ (Uong, 2012) and altering this ratio the “DS vs. acoustical anatomical functional ratio.”

Our findings confirm that vowel production is atypical in individuals with DS, particularly the back vowels /u/ and /o/.

METHODS
Participants
46 individuals with Down syndrome (DS): 26 males and 20 females; ages 5.1-36.6 yrs, mean age = 10.0 yrs. Typically developing individuals (TD): 34 males and 41 females; ages 4.4-64.5 yrs, mean age of 14.9 yrs.

Stimuli
Stimuli were obtained from a repetition task using 40 familiar monosyllabic words (e.g., “bead” and “bed”) and 40 words for each of the five corner vowels. Each word was represented in five different test words. Stimuli were recorded with a Marantz digital recorder paired with a TOSCa Platform (speech testing software) for randomization. Stimuli were presented visually and audurally.

Acoustic Analysis
The acoustic parameters for each word were first segmented with the software Praat to select a segment for formant analysis. Vocal fundamental frequency and the frequency of the first three formants were measured using the software TFS. Formant frequency analysis was accomplished with Fast Fourier Transform (FFT) spectrograms overlaid with Linear Predictive Coding (LPC) formant tracks. If needed, a spectral slice was generated to show the FFT and LPC spectra calculated for the selected vowel segment.

RESULTS
Table 1: Values for Vowel Articulation Index (VAI) and Vowels and Articulatory Functional Ratio (VFR). Values summarized for all TD and DS participants. The vowel quadrilateral is divided into four age groups

<table>
<thead>
<tr>
<th>Age Group</th>
<th>All Ages</th>
<th>VAI (SD)</th>
<th>VFR (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-10 yrs</td>
<td>M=34</td>
<td>T2=2.41</td>
<td>T1=1.12</td>
</tr>
<tr>
<td>11-15 yrs</td>
<td>M=37</td>
<td>T2=2.34</td>
<td>T1=1.07</td>
</tr>
<tr>
<td>16-20 yrs</td>
<td>M=34</td>
<td>T2=2.34</td>
<td>T1=1.07</td>
</tr>
<tr>
<td>21+ yrs</td>
<td>M=20</td>
<td>T2=2.30</td>
<td>T1=1.09</td>
</tr>
</tbody>
</table>

CONCLUSIONS/IMPLICATIONS
1. Our findings confirm that vowel production is atypical in individuals with DS, particularly the back vowels /u/ and /o/.

2. Such findings may be related to the reduced speech intelligibility that individuals with DS typically experience.

3. The difficulties of vowel production could be related to craniofacial anomalies, disordered motor control, failing phonological representation, or some combination of these. Uong et al. concluded in a WRT study that DS is associated with a reduction in upper airway size resulting from soft tissue crowding within a smaller mid-face and lower face skeleton. But motor problems, such as hypotonia, also could contribute to difficulties in articulator activity.

4. Acoustic measures of vowels are an objective index of articulatory ability in individuals with DS and could be used to assess the outcomes of interventions.

5. Studies of articulatory and phonological errors in DS may show that the patterns are a complex blend reflecting both development errors and atypical errors.

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SELECT REFERENCES: This poster can be found at: http://waisman.wisc.edu/vocalposters/911_sing.pdf

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