F2/F1 VOWEL QUADRILATERAL AREA IN YOUNG CHILDREN WITH AND WITHOUT DYSARTHRIA

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INTRODUCTION

Previous studies have examined the formant frequencies of vowels produced by children with normal speech development[1,2,3,4]. As expected from acoustic theory, these studies have found that formant frequencies of vowels decrease as a child's age, and vocal tract size, increases. Formant frequencies appear to reach adult values around the age of 12 or 13 years[4]. Kent[5] identified vowel area as one of several acoustic correlates of speech intelligibility. One method of estimating vowel area is to use coordinates of the first (F1) and second (F2) formants of the four point vowels (high front, low front, low back, and high back) to plot a quadrilateral and then determine its planar area.

Using reported formant values[1,2,3,4] it can be shown that the F2/F1 vowel quadrilateral area decreases in size as age increases, that is, when F1 by F2 vowel area is determined using formant frequency values expressed in Hz, intertalker comparisons of vowel are size are confounded by differences in vocal tract size[6]. Differences between acoustic vowel measures produced by individuals with and without dysarthria have also been reported[7,8]. Nearey[9] predicted that a $\log_n$ Hz scale would normalize vocal tract size differences when comparing formant frequency values. Therefore it was of interest to determine if use of a $\log_n$ Hz scale would eliminate the effect of vocal tract size on vowel area across a broad age range of talkers and also be sensitive to potentially smaller vowel areas of dysarthric individuals.

The objectives were to:

1) Extend the results of previous work by testing hypotheses about the effect of age (vocal tract size) on vowel area, expressed in Hz and $\log_n$ Hz scales. It was predicted that a $\log_n$ Hz scale would eliminate the effect of vocal tract size differences on vowel area that are evident in the Hz scale.
2) Test the hypothesis that vowel areas of children with dysarthria would be significantly smaller than those of age-matched peers with normal speech production.
3) Examine the relationship between speech intelligibility and vowel area in age-matched children with and without dysarthria.

METHODS

2.1 Subjects

Recordings produced by six 3 year-old children, six 5 year-old children and six young women, all with normal speech development, and six 5 year-old children with dysarthria were analyzed for this study. Of the children with dysarthria, three were diagnosed with a lower motor neuron impairment and three were diagnosed with central nervous system impairment. Identification rates obtained from normal adults listeners for the vowels in the recorded words used in this study were high for the normally speaking children (Mean = 94.7%; SD = 3.1%), and lower for the dysarthric children (Mean = 70.7%; SD = 16.8%).

2.2 Audio Recordings

Digital audio recordings from the subjects' productions of a subset of 24 words from Form 1: Word Test of Children's Speech (W-TOCS)[10] were measured. Six words were used for each of the point vowels /i/, /æ/, /a/ and /u/ for Western Canadian English.

2.3 Formant Measurement

F1 and F2 values were estimated for each vowel token from wideband spectrograms generated using CSpeech 4.0[11]. A 30 ms window within the vowel was isolated for measurement. This section was taken from a point in the vowel judged to be the most stable. F1 and F2 values in Hz for each vowel token were converted into $\log_n$ Hz and then averaged for each vowel for each subject. F2/F1 planar area for each subject's vowel quadrilateral was calculated in Hz and $\log_n$ Hz scales.

RESULTS

Mean vowel areas in Hz and $\log_n$ Hz scales for each subject group are shown in Table 1. As predicted, for the Hz scale, vowel quadrilateral areas for adult women were smaller than those of children. Older children (5 years) had smaller vowel areas than younger children (3 years). A one-way ANOVA revealed a significant age effect ($F=22.241$, $p=.0001$). Post-hoc analysis revealed significant differences between all age group pairs.

When formant measures were converted to the $\log_n$ Hz scale, a significant difference in vowel quadrilateral area was also found between subject groups ($F= 9.318$, $p=.0023$). Post-hoc analysis revealed that vowel area, calculated in

$log_n Hz^2$, was significantly larger in three year-olds than in the women (p=.0024) but that there was not a significant difference between the 5 year-olds and the 3 year-olds (p=.0813) or between the women and the 5 year-olds (p=.2100).

Results of a one-way ANOVA demonstrated that the dysarthric children had significantly smaller vowel quadrilateral areas, calculated in $log_n Hz^2$, than their age-matched, normally speaking peers (F=5.275, p=.0445).

Vowel quadrilateral areas in $log_n Hz^2$ for the 5 year-old children with and without dysarthria were correlated with their single word intelligibility scores on the complete W-TOCS. Results showed a moderately strong positive correlation between vowel area and intelligibility scores (r =. 71).

Table 1. Mean F2/F1 vowel quadrilateral areas in Hz^2 and $log_n Hz^2$ for subject groups.

	3 year-olds	5 year-olds	Women	Children (Dysarthria)
Hz^2	1078736	748862	468055	527487
(SD)	(94522)	(226980)	(123190)	(122869)
$log_n Hz^2$	.624	.444	.301	.294
(SD)	(.13)	(.16)	(.09)	(.06)

4. CONCLUSIONS

Vowel area, when measured in Hz^2 and $log_n Hz^2$, decreases in size as age increases, suggesting that a log_n Hz scale does not normalize age differences in F2 by F1 vowel area. However, factors other than vocal tract size, such as articulatory differences, might account for age differences in acoustic space.

Vowel areas of children with dysarthria are smaller than those of their age-matched peers.

There is a moderately strong positive correlation between intelligibility scores on the W-TOCS and vowel quadrilateral area, expressed in $log_n Hz^2$.

Future research will address whether using only vowels that have been identified accurately will reduce differences in vowel quadrilateral area found between children with and without dysarthria.

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