ICA 2013 Montreal
Montreal, Canada
2 - 7 June 2013

Speech Communication

Session 2aSC: Linking Perception and Production (Poster Session)

2aSC57. Acoustic vowel space and speech rate in Mandarin-speaking children with cerebral palsy

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This study examines the variability in speech production in 4 Mandarin-speaking children: two with cerebral palsy (CP) and two typically developing (TD) from 4 to 5 years of age. Recordings collected from the picture-naming task and spontaneous interaction was analyzed. Acoustic vowel space and speech rate were investigated. Study findings indicated: 1) Due to defect in speech motor control, children with CP have a smaller overall vowel space; 2) In CP group, there are more variability of formant values of individual vowels and the vowel space of individual vowels thus overlap more; 3) There is a trend of decrease of vowel formant values in both TD and CP; 4) Children with CP tend to spend more time in speech production because of their impaired speech-motor control, in terms of syllable per minute and intelligible syllable per minute; and 5) Slower speech rate seems to increase speech intelligibility in CP. However, this needs to be verified in further studies. Extended longitudinal observation can provide more complete profile of individual differences in the development of vowels and speech rate to verify these preliminary findings. The variability features in the production of children with CP provide important references in speech therapy.

Published by the Acoustical Society of America through the American Institute of Physics
INTRODUCTION

Due to the neurologic factors, children with cerebral palsy (CP) tend to have several types of speech deficits. According to Ciocca, Whitehill & Joan (2004), 60% of children with CP have some type of speech deficits, among which dysarthria, the most common speech disorder found in individuals with CP, has received more attention.

A number of studies had discovered the variability of vowel space in children with dysarthria as compared with typically developing children (Hustad, Gorton, & Lee, 2010; Sapir, Ramig, Spielman, & Fox, 2010; Chen, Ni, Kuo, 2012). Chen et al (2012) had investigated the acoustic variability in Mandarin-speaking children with CP. They discovered that children with CP tend to have smaller vowel space than the TD children and lower speech rate and speech intelligibility. In this current study, data from two of the CP participants in Chen’s et al (2012) were further analyzed by looking at the changes in vowel space in one year term.

Due to the neuromuscular factors, individuals with dysarthria tend to have slower and more unstable speech rate (Kent & Kim, 2003; LeDorze, Ouellet, & Ryalls, 1994; Hustad & Sassano, 2002; Weismer, Laures, Jeng, & Kent, 2000). Hustad et al. (2010) indicated that slower speech rate of individuals with cerebral palsy may contribute to higher speech intelligibility, which also serves as an aid to their communication efficiency. However, other studies have found no significant correlation. Whether the slower speech can be a compensatory strategy to increase intelligibility remains unknown. This study explores the relationship between speech rate and speech intelligibility in spontaneous speech in 4-year-olds with cerebral palsy.

METHODOLOGY

The Participants

Four children participated in this study: two with cerebral palsy (CP1 and CP2) and two typically developing children with no specific medical history, TD1 (age in months 54.5/50.5) and TD2 (55.1/67.3).

<table>
<thead>
<tr>
<th>TABLE 1. Descriptive data of the two CP children</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>CP1</td>
</tr>
<tr>
<td>CP2</td>
</tr>
</tbody>
</table>

All of the children are male, in order to avoid any potential gender differences in pitch, and have normal hearing and intelligence. The two CP children were recruited from a hospital. The data of TD children were taken from a large-scale study of longitudinal phonetic development.

Data Collection and Analysis

A SHURE Wireless microphone system was linked to TASCAM DR-100 recorders for audio recording. During the 50-minute observation period, speech productions in picture naming task were recorded, and the Peabody Picture Vocabulary Test-Revised (PPVT-R) was used to provide a quick assessment of the speech and language ability. Moreover, sentence productions were elicited with repetition of hundreds of four-word sentences.

In the present study, every word in picture-naming task was transcribed. Then the first (F1) and the second formant (F2) frequencies were determined with reference to Linear Prediction Coefficient (LPC) and Fast Fourier Transformation (FFT) which were analyzed with the time-frequency analysis software, TF32 (Milenkovic, 2005). About 20 items of the following vowel categories /i, e, o, a, a/ were transcribed and analyzed.

In speech rate, the target data were the phrases and sentences produced by the four children in spontaneous interaction and elicitation. To examine speech intelligibility, the target data were 50 randomly chosen words from the picture-naming task in the same recordings. The following principles were followed.

1. Syllables per minute (SPM): one judge listened to the phrases and sentences, transcribed syllable by syllable, and counted the number of the syllables. SPM is obtained by calculating the total number of the syllables divided by the time duration, and multiplying the quotient by 60. In the case of spontaneous speech and elicitation data, the intra-sentence pauses were included, but the inter-sentences pauses were not.

2. Intelligible syllables per minute (ISPM): ISPM is acquired by counting only the number of the intelligible syllables divided by the duration, and multiplying the quotient by 60. Ten percent of the data were re-analyzed by
the second judge. The result of inter-judge reliability is 86.2%, which exceeds the criteria proposed by Kassarjian (1997).

In speech intelligibility, three judges were recruited to transcribe productions of 50 words of each child in the picture naming tasks and sentence elicitation. The judges could only listen once and then transcribed what they heard. All the judges worked alone, and at their own pace. The total number of correctly transcribed syllables was divided by the total number of the syllables of the 50-word list and sentence elicitation. Mean intelligibility from the three judges was calculated as speech intelligibility of each child.

RESULTS & DISCUSSION

Vowel Space

We first investigated the changes in F1 and F2 values which Tables 2 and 3 show the mean F1 and F2 as a function of age at four stages in one year.

**TABLE 2.** Medians of F1 and F2 values for CP1 in four stages

<table>
<thead>
<tr>
<th>Age</th>
<th>/i/ F1</th>
<th>/e/ F1</th>
<th>/u/ F1</th>
<th>/a/ F1</th>
<th>/o/ F1</th>
<th>/i/ F2</th>
<th>/e/ F2</th>
<th>/u/ F2</th>
<th>/a/ F2</th>
<th>/o/ F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3;11,6</td>
<td>610</td>
<td>754</td>
<td>1259</td>
<td>989</td>
<td>2222</td>
<td>814</td>
<td>2184</td>
<td>813</td>
<td>1594</td>
<td></td>
</tr>
<tr>
<td>4;4,28</td>
<td>652</td>
<td>3018</td>
<td>1085</td>
<td>2249</td>
<td>819</td>
<td>2200</td>
<td>882</td>
<td>1739</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4;7,6</td>
<td>597</td>
<td>706</td>
<td>1188</td>
<td>2237</td>
<td>727</td>
<td>2214</td>
<td>771</td>
<td>1572</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4;10,5</td>
<td>730</td>
<td>1077</td>
<td>778</td>
<td>2213</td>
<td>779</td>
<td>2367</td>
<td>612</td>
<td>2586</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 2, the results reveal that F2 values of /i/ and /e/ declined, whereas, F1 values increased after a year of study. On the other hand, the F2 values of /u/ and /o/ increased.

**TABLE 3.** Median of F1 and F2 values for CP2 in four stages

<table>
<thead>
<tr>
<th>Age</th>
<th>/i/ F1</th>
<th>/e/ F1</th>
<th>/u/ F1</th>
<th>/a/ F1</th>
<th>/o/ F1</th>
<th>/i/ F2</th>
<th>/e/ F2</th>
<th>/u/ F2</th>
<th>/a/ F2</th>
<th>/o/ F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4;8,8</td>
<td>551</td>
<td>772</td>
<td>1382</td>
<td>858</td>
<td>1882</td>
<td>731</td>
<td>1766</td>
<td>784</td>
<td>1417</td>
<td></td>
</tr>
<tr>
<td>4;11,16</td>
<td>479</td>
<td>731</td>
<td>1008</td>
<td>1810</td>
<td>817</td>
<td>1766</td>
<td>666</td>
<td>1294</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5;5,0</td>
<td>508</td>
<td>817</td>
<td>1213</td>
<td>741</td>
<td>1375</td>
<td>951</td>
<td>1684</td>
<td>685</td>
<td>1635</td>
<td></td>
</tr>
<tr>
<td>5;8,11</td>
<td>541</td>
<td>696</td>
<td>602</td>
<td>901</td>
<td>1903</td>
<td>603</td>
<td>1723</td>
<td>726</td>
<td>1342</td>
<td></td>
</tr>
</tbody>
</table>

Results as shown in the Table 3 reveal that only vowel /a/ has decreasing F2 value and increasing F1 value. Figures 1 and 2 below illustrated the vowel space for individual CP children in four stages.
As shown in Figure 1, the ranges of each density ellipse become more regular and centroids with age. However, Figure 2 appears no obvious changes of vowel space area, and the overlapping of ellipses did not become smaller.

According to Ishizuka et al (2007) that the vowel space should expand in process with age, since the tongue position expands with more flexible jaw motor ability. However, the results shown on Figures 3 and 4 reveal that the two vowel space areas from CP1 and CP2 become smaller with age.

Speech Rate

Both SPM and ISPM of CP1 and CP2 are slower than TD1 and TD2. (1) SPM: In spontaneous interaction, SPM of CP2 was 239, which could almost compete with the TD children, which were 254 SPM and 272 SPM respectively. As to speech rate in elicitation data, both CP children were slower than TD2, but the results were close to each other. The results of SPM were 195 and
209 in CP1 and CP2, 201, and 224 in TD1 and TD2.

(2) ISPMP: the differences between CP children and TD children are extended. While the rates of typically developing children remain almost the same, the rates of CP children dropped much more slowly, especially in CP2. CP2 produced a fast speech rate with low intelligibility.

As to speech intelligibility in spontaneous interaction, the results in CP1 and CP2 were 76% and 63%, and in TD1 and TD2 were 98% and 92%, respectively. There is an obvious difference between CP children and TD children in speech rate. Both CP1 and CP2 showed a lower intelligibility. Moreover, CP2’s speech intelligibility was only 63%, which was the lowest of the four children. Compared with CP children, TD1 and TD2 showed relatively high intelligibility, at 98% and 92% respectively. CP2 was a fast speaker, and his speech intelligibility was affected by this rapidness and dropped more apparently than other three children. While CP1 showed slower speech rate, and his speech intelligibility was higher than CP2.

Individual differences in CP children were observed. CP2 showed similar speech rate as the TD group in SPM, and a much faster speech rate than CP1. This might be due to the different type of cerebral palsy. In this study, although CP1 was less severe than CP2 in cerebral palsy, CP1 was diagnosed with dyskinetic quadriplegia, and this type of cerebral palsy usually affects the speech production more obviously. Ingram and Barn (1961) proposed that the reason leading to dyskinetic dysarthria is generally because the motor control of the voluntary articulator in dyskinetic speakers has been aggravated by their involuntary movements, which leads to the disruption of the speech. CP2’s fast speech might result from the repetition of the target items in picture naming task. Through these repetitions, the duration of the repeated utterances became shorter. In the repetition productions in elicitation, CP2 even showed larger SPM than TD1. The repeated utterances of spontaneous interaction take up 15% of the whole data, which might explain the fast speech rate of CP2. Furthermore, while examining the repeated utterances in CP2, it was found that CP children have the ability to adjust their speech rate at will. In our observation sessions, when CP2 was mischievously playing with adults, he obviously slowed down or sped up the rate of the target utterances. They can be capable of planning speech production. The rate flexibility in CP children in this current study might suggest that the speech deficit in dysarthric speakers is a matter of performance, not of competence as mentioned in LeDorze et al. (1994).

REFERENCES


