Vowel production in cri du chat-syndrome – a case study

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ABSTRACT

This paper presents results from a longitudinal study of vowel productions by a girl (H) with cri du chat syndrome (CDCS). Vowel productions in recordings of H's speech at two different times (4;6 and 7;0) were subjected to acoustic analysis. The vowels were classified with reference to the corresponding vowels in target words, and formant frequency measurements were made of them from spectrograms. The results show that for all the vowels analyzed both F1 and F2 varied considerably. Furthermore, analyses of F1/F2 plots at both 4;6 and 7;0 revealed that H's vowel productions did not form the well developed vowel space that is seen in normally developed children at H's age. In spite of this, the data clearly indicate that from 4;6 to 7;0 a distinction between close and non-close vowels developed.

1. INTRODUCTION

CDCS is a rare genetic disorder (1 in 50 000 births) resulting from loss of genetic material from the short arm of chromosome 5. Symptoms include high-pitched cry (perceptually and acoustically similar to the mewing of kittens)[1], hypotonia and delayed linguistic development, most notably a discrepancy between chronological and linguistic age and between receptive and expressive linguistic abilities[2], [3], [4]. Furthermore, most children with CDCS have severe articulatory problems.[3], [5], [6]

2. THE SUBJECT (H)

H has been raised in a monolingual Norwegian-speaking environment. Her target language is Urban East Norwegian (UEN).[7] UEN has the following vowel phonemes in stressed syllables:

Long: /iː, yː, ʉː, uː, eː, øː, oː, æː, aː/
Short: /i, y, ʉ, u, e, ø, o, æ, a/

Vowels in unstressed syllables are always short. In this paper I focus on vowels in H's speech which correspond to stressed vowels in the target words corresponding to H's words in which these vowels appear. Of the vowels in UEN, all but two, /æ/ and /æː/, appears in the material. Another one, /eː/ is missing from the recordings at 4;6. These shortcomings arise from the fact that the test materials which were used for the study of H's speech, were primarily devised to elicit consonants in the target language.

In what follows, I use the term *vowel type* to refer to any of the target vowels of UEN, and the term *vowel token* to refer to any vowel in H's speech that is an attempt to reproduce one of these vowel types.

H's speech is severely disordered. A longitudinal study of the development of H's consonants has shown that[5], [6]

- her consonant inventories were considerably more restricted than normally developing children the same age;
- these inventories showed little development over the 2 1/2 years during which the study was conducted;
- hypotonia was a likely cause for the restricted inventories and the lack of development.

In one of these papers also H's vowel productions were briefly described. This description was based on an articulatory classification of perceived sounds[6]. It was pointed out that H's vowels appeared to cluster in a few areas in the vowel quadrilateral, and that most vowels with the exception of a front close vowel appeared to vary considerably with respect to both the close-open dimension and the front-back dimension.

3. RESEARCH QUESTIONS

Clearly, such a perceptually based articulatory classification gives less reliable phonetic data than do

acoustic analyses. Thus, in the present study I look at H's vowel productions against the background of previous acoustic studies of vowel productions in infants and toddlers[8], [9], [10]. Important results of these earlier studies are:

- In terms of F1/F2 plots, vowel productions in infants and toddlers vary considerably; furthermore, there is considerable acoustic overlap between perceptually similar vowels.
- During the first 36 months of life, a vowel space gradually emerges; the front axis of this vowel space emerges before the back axis. This difference between front and back vowels is attributed to the fact that production mechanisms are more complex for back vowels than for front vowels.

The main aim of this paper is to look at acoustic properties of H's vowels, and to compare them with the results of these earlier studies. The paper aims at answering the following two research questions:

- Is there any sign of a vowel space in H's speech at 4;6, or does a vowel space emerge from 4;6 to 7;0?
- Are various tokens of the same vowel type in H's speech similar with respect to formant frequencies, or is there much variation with respect to formant frequencies?

4. METHOD

For the purpose of the present and previous studies of H's speech, her development has been followed over a period of 2 1/2 years, starting when she was 4;6 and ending when she was 7 years of age. Recordings were made at three points during this period, at 4;6, 5;9 and 7;0. This paper presents analyses of vowels in the recordings at 4;6 and 7;0.

The recordings represent speech elicited by a picture and object naming test developed on the basis of the author's knowledge of H's active vocabulary. At both stages about 100 words were elicited.

The material used in the present paper consists of 136 vowel tokens, 65 at 4;6 and 71 at 7;0. The numbers of corresponding short and long vowels in the target words are given in table 1.

	Short vowels in target word	**Long vowels in target words**
4;6	30	34
7;0	35	37
Total	65	71

Table 1: *Number of vowels in the material corresponding to short and long vowels in the target words*

These vowel tokens represent H's attempts at producing the following target vowels (number of tokens in parentheses):

- *Short target vowels at 4;6:* /i/ (5), /e/ (5), /a/ (5), /y/ (1), /ʉ/ (2), /u/ (4), /ø/ (3), /o/ (5)
- *Long target vowels at 4;6:* /i:/ (5), /a:/ (4), /y:/ (6), /ʉ:/ (7), /u:/ (4), /ø:/ (4), /o:/ (3)
- *Short target vowels at 7;0:* /i/ (6), /e/ (6), /a/ (5), /y/ (1), /ʉ/ (3), /ø/ (4), /o/ (5)
- *Long target vowels at 7;0:* /i:/ (5), /e:/ (3), /a:/ (5), /y:/ (2), /ʉ:/ (5), /u:/ (5), /ø:/ (5), /o:/ (5)

The recordings were made in H's home by the author, using a Sony minidisc recorder. They were replayed on a minidisc recorder connected to an Apple computer, where spectrograms of each vowel token were made in *Praat* (version 4.0.41). The formant frequency measurements presented in the following section are taken from these spectrograms.

5. RESULTS

In this section acoustic data on the 71 vowel tokens in my material are presented. In subsection 5.1 mean values of F1 and F2 for each vowel type are given, and in subsection 5.2 F1/F2 plots for each vowel type at 4;6 and 7;0 are compared.

5.1 Frequency values of first and second formants

In table 1 the mean frequency values for first and second formants for each long target vowel are given:

	4;6		**7;0**	
	F1	*F2*	*F1*	*F2*
/i:/	0.5	1.2	0.5	2.1
/y:/	0.6	1.5	0.4	2.3
/ʉ:/	0.5	1.5	0.7	1.4
/u:/	0.6	1.8	0.7	1.3
/e:/			0.7	2.0
/ø:/	0.6	1.5	0.9	1.6
/o:/	0.5	1.2	0.8	1.6
/a:/	0.8	1.7	1.0	1.7

Table 2: *Mean values for F1 and F2 of long vowels*

Table 2 shows that H's reproductions of the long close vowels /i:/, /y:/, /ʉ:/ and /u:/ have low F1 values at 4;6. However, at 4;6 also tokens of the long mid vowels have relatively low F1 values. In fact, only the long open vowel at this stage has a slightly higher F1 value.

If we turn to F2 values of tokens of long target vowels at 4;6, the picture is to some extent different: Among the close vowels, there is a gradual increase in F2 value from /i:/ to /u:/. However, there is no distinction between /y:/ and /ʉ:/ with respect to F2 value. Furthermore, there is no difference in F2 value between the mid front /ø:/ and the back front /o:/ at 4;6.

In sum, there is no indication in the acoustic data

considered here of a systematic close-open distinction in H's production of long vowels at 4;6. On the other hand, there is some indication in these data of a front-back distinction in H's reproduction of long close vowels at this age.

If we turn to the mean formant frequency values at 7;0 the picture changes somewhat. On the one hand, there is a clearer indication of a close vs. non-close distinction in the data: tokens of /i:/ and /y:/ both have low F1 values, as compared to tokens of the mid vowels /e:/, /ø:/ and /o:/. On the other hand, the F1 values of tokens of /a:/ are not markedly different from those of the mid vowels. Furthermore, the close target vowels and /ʉ:/ and /u:/ pattern with the mid vowels with respect to F1 values.

Turning to F2 values at 7;0, there is a clear distinction between tokens of /i:/ and /y:/ on the one hand, and between tokens of /ʉ:/ and /u:/ on the other. Similarly, among the mid vowels, there is a distinction between tokens of /e:/, with a mean F2 value fo 2.0 kHz, and /ø:/ and /o:/, both having mean F2 values of 1.6 kHz. That there is no distinction in F2 values between /ʉ:/ and /u:/ and between /ø:/ and /o:/ points to problems with the front vs. back distinction.

Turning now to short vowels, table 3 shows the mean frequency values of first and second formants of short vowels in the material:

	4;6		**7;0**	
	F1	*F2*	*F1*	*F2*
/i/	0.6	1.5	0.5	2.1
/y/	0.5	2.0	0.6	1.6
/ʉ/	0.7	1.5	0.8	1.5
/u/	1.0	2.0	0.8	1.4
/e/	0.8	1.7	1.0	1.9
/ø/	0.6	1.3	0.8	1.6
/o/	0.8	1.8	0.8	1.4
/a/	0.8	1.8	1.0	1.9

Table 3: *Mean values of F1 and F2 for short vowels*

The picture that emerges from this table is not very different from the one presented for the long vowels: At 4;6 there is no clear support for a height distinction, and even less support for a front-back distinction among the close vowels than with the long vowels.

At 7;0, on the other hand, there is support for a height distinction between tokens of the two close vowels /i/ and /y/, and tokens of all other target vowels, close, mid or open (cf. the F1 values). There is also support for a front-back distinction similar to the one noted for the long vowels, where tokens of /i/ have higher mean F2 value than tokens of /ʉ/ and /u/. But again H does not seem to make a distinction in terms of F2 value between either /ʉ/ and /u/ or between /ø/ and /o/.

5.2 F1/F2 plots

By giving mean values for first and second formant frequencies in the preceding subsection, we have overlooked the fact that H's vowel productions are extremely variable. To give an impression of this variation I conclude this section by giving F1/F2 plots for short and long vowels at 4;6 and 7;0:

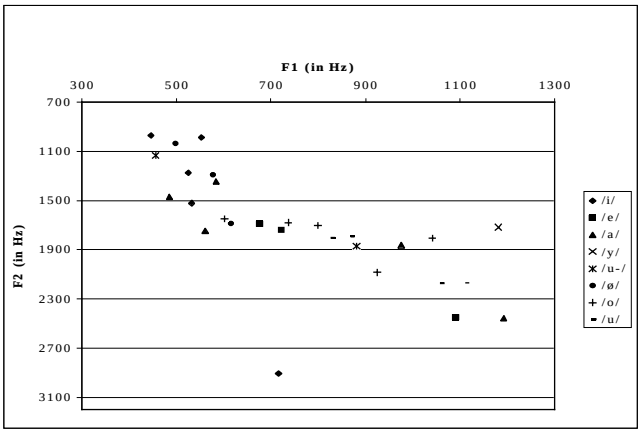

Chart 1: *F1/F2 plots of short vowels at 4;6*

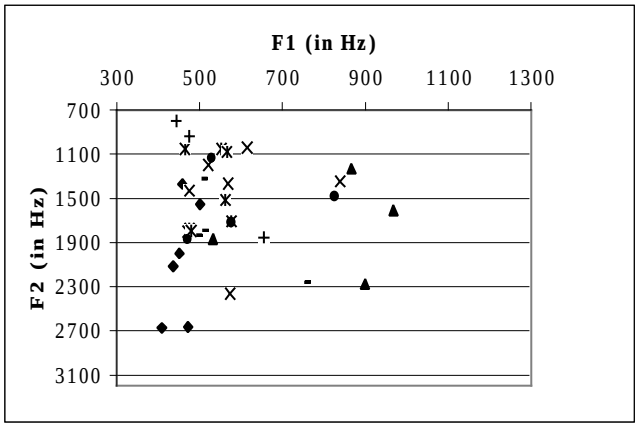

Chart 2: *F1/F2 plots of long vowels at 4;6*

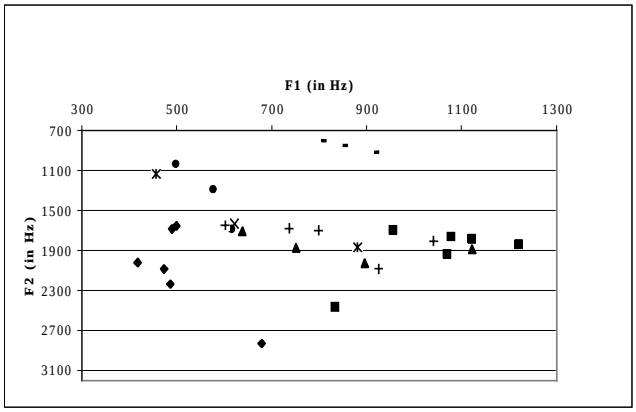

Chart 3: *F1/F2 plots of short vowels at 7;0*

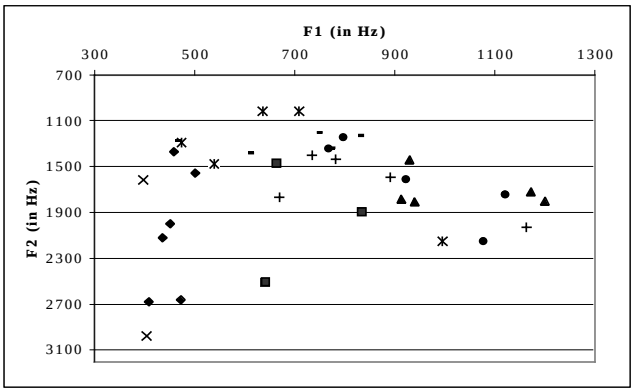

Chart 4: *F1/F2 plots of long vowels at 7;0*

Charts 1 to 4 reveal that there is a lot of variation within H's production of each of the UEN target vowels. Furhermore, there are few signs of a well-developed vowel triangle in these charts.

6. SUMMARY AND CONCLUSIONS

In this paper I have presented results from a longitudinal study of vowel productions in a girl with cri du chat syndrome. The study has shown that

- vowel productions in terms of frequency values for first and second formants varied considerably;
- there were few signs of a acoustic vowel space in these productions;
- however, between 4;6 and 7;0 a distinction between close and non-close vowels appeared

These results points in the same direction as the results from the two earlier studies of the development of H's consonants from 4;6 to 7;0. It was shown that her consonant inventories were heavily restricted, and it was hypthezised that the small size of these inventories mainly was the result of hypotonia. In my view, lack of muscular control is also a very reasonable explanation for the variation in tokens of the same target vowels we see in charts 1-4 above.

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