Articulation of consonants in cri du chat syndrome – a gestural approach

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1. Introduction

This paper deals with consonant production in Cri du chat syndrome. Persons with this syndrome have problems to varying degrees with both language reception and language production, and consonant productions have been shown to be both delayed and deviant compared to persons with normal language abilities (Kristoffersen, 2003a, b; 2004). Prominent aspects of delayed and deviant consonant productions in one subject will be described and analyzed within the theoretical framework of articulatory phonology (Browman and Goldstein, 1989, 1992; Byrd, 2003; Studdert-Kennedy and Goldstein, 2003). In articulatory phonology articulatory gestures have a key function in phonological descriptions, and it has been argued that this framework is better suited to account for at least some variants of disordered speech and phonology than feature- and segment based frameworks (Weismer, Tjaden and Kent, 1995; Moen, 2004). This is the main reason for choosing articulatory phonology as theoretical framework in the present context.

The paper presents, first, a description of various classes of production errors the subject’s consonant productions. Second, it investigates to what extent these deviant and disordered consonant productions can be accounted for in terms of articulatory phonology. The paper is organized as follows: In section 2 a presentation of cri du chat syndrome is given – focusing both on general characteristics of the syndrome and on language abilities. In section 3 the subject of this study is presented. In section 4 methodological considerations are discussed, and in section 5 the
theoretical framework for this study is outlined. Section 6 presents an analysis of consonant productions within this framework, and section 7 sums up the paper.

2. Cri du chat syndrome

2.1. General features

Cri du chat syndrome (CDCS) is a rare genetic disorder (with an estimated incidence between 1:25,000 and 1:50,000 births), associated with a deletion of material on the short arm of chromosome 5. The syndrome was first described by Lejeune, Lafourcade, Berger, Vialette, Boeswillwald, Serginge and Turpin (1963). Features, which vary considerably from patient to patient, include a high-pitched cry in infancy and childhood (Sohner and Mitchell, 1991), and for some also in adulthood, malocclusion, hyper- and hypotonia (Carlin, 1990), microcephaly (Niebuhr, 1978), various degrees of intellectual disability – from mild to profound (Cornish, Bramble, Munir and Pigram, 1999), short attention span, hyperactivity, stereotyped, aggressive and self-injurious behaviour (Collins and Cornish, 2002), delayed motor development (Carlin, 1990) and delayed speech and language development.

2.2. Speech and language development in CDCS – previous studies

The early literature gives little specific information about speech and language abilities in patients with CDCS. For example, Silber, Engel and Merril (1967) described a 7 year-old girl with this syndrome, reporting that her first word appeared at 2 years. Nothing else is said about her language development.

Schlegel, Neu, Carneiro Leao, Reiss, Nolan and Gardner (1967) reported a case of a girl aged 10;3, with a full scale Stanford-Binet IQ of 58. Her receptive language abilities were reported to be on about 3 year level, and her articulation was characterized by substitutions and omissions of sounds. Moreover, she was said to “use actual words, not jargon, for pleasure and to communicate”.

Sparks and Hutchinson (1980) reported a case of a girl, C., aged 7;6 who had received early and intensive speech and language therapy. Therapy began at 2;6. At 3 C. was reported to use two-word phrases. IQ was measured to 53 (with Stanford Binet L-M Intelligence Test) at 4;9, and again at 7;6 (Full Scale Stanford Binet IQ test), this
time with a resultant IQ of 42. At 7;6 her articulation is reported to be characterized by omissions and substitutions, and she tended to omit “word endings” (p 12). Examples of spontaneous utterances in C’s speech: help me, I go down, I love you, two black eyes, he is jumping.

Wilkins, Brown and Wolf (1980) investigated psychomotor development in 65 home-reared US children with CDCS (age range: 0;2 – 26 years; mean age males: 8 years; mean age females: 6;2), and found that 50 % were able to use language “to express needs and emotions”. Eleven of their subjects had vocabularies of more than 100 words and were able to use sentences consisting of three or more words. In addition, 24 subjects had “limited but useful single word vocabularies”.

Carlin (1990), reporting from a study of 62 patients with cdcs, noted that (p 64) speech had developed in 50 % of the subjects while 75 % of them used signing or other communication methods. One problem with these results is that it is not made clear what is meant by the term speech.

Sohner and Mithcell (1991) studied early phonetic and phonatory development in comfort state vocalizations in one child longitudinally (8 – 26 months), and reported a high fundamental frequency (mean 585.38 Hz) and delayed phonetic development, in particular delayed onset of babbling. Furthermore, their subject had no words in production at 26 months of age.

Cornish and Pigram (1996) studied a population of 27 children (mean chronological age: 8;3; range 4;0 – 16;0) with CDCS in the UK, whose behavioural characteristics were assessed by means of a questionnaire (the Society for the Study of Behavioural Penotypes questionnaire). The ability to communicate was assessed on the basis of how the subjects made needs known. Cornish and Pigram showed in their study that 25.9% used speech, whereas 7.4% used formal sign or symbol system. Furthermore, 48.1% of the subjects in this study communicated their needs by means of “non-verbal method”, and 18.5% did not indicate needs at all.

Cornish and Munir (1998) studied receptive and expressive language skills in 13 UK children with CDCS (mean age 8;10; age range 4 – 14). Their comprehension of vocabulary was measured by the British Picture Vocabulary Scales (BPVS) (Dunn, Dunn, Whetton and Pintile, 1982), their comprehension of grammar was measured by the Test of the reception of grammar (TROG) (Bishop, 1983), and their expressive
language abilities were measured by the *Reynell Language Development Scales* (RLDS) (Reynell, 1985). Results are presented in table 1.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPVS (10 children)</td>
<td>4.3 years</td>
<td>2 – 12.2 years</td>
</tr>
<tr>
<td>TROG (10 children)</td>
<td>4.1 years</td>
<td>4 – 11 years</td>
</tr>
<tr>
<td>RDLS (13 children)</td>
<td>1.5 years</td>
<td>1 – 7 years</td>
</tr>
</tbody>
</table>

Table 1

*Results from Cornish and Munir 1998*

As table 1 shows, Cornish and Munir (1998) found a discrepancy between chronological age and linguistic age (as measured by the tests). Furthermore, they found a discrepancy between receptive and expressive skills in their subjects, in that language comprehension was significantly better than language production.

Cornish, Bramble, Munir and Pigram (1999) studied the cognitive functioning in 26 UK children with CDCS (mean age 8;3. Age range: 6;4 – 15;5) using the *Wechsler Intelligence Scale for Children* (WISC-III) (Wechsler 1992), BPVS, TROG, the *Goldman-Fristoe Test of Articulation* (GFTA) (Goldman and Fristoe, 1986), the *Expressive One Word Picture Vocabulary Test – Revised* (EOWPVT-R) (Gardner 1990) and the expressive language section of RLDS. The results for the assessment of language skills (except for articulation as measured by GFTA) are displayed in table 2.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPVS (23 children)</td>
<td>4.38 years</td>
<td>2 – 7 years</td>
</tr>
<tr>
<td>TROG (19 children)</td>
<td>4.85 years</td>
<td>4 – 6 years</td>
</tr>
<tr>
<td>RDLS (24 children)</td>
<td>1.75 years</td>
<td>1 – 5 years</td>
</tr>
<tr>
<td>EOWPVT-R (11 children)</td>
<td>2.7 years</td>
<td>2 – 5 years</td>
</tr>
</tbody>
</table>

Table 2

*Results from Cornish et al. (1999)*

We see that this study confirms the results of the previous study by Cornish and Munir (1998) – a discrepancy between language age and chronological age, and a discrepancy between language production and language comprehension.

A few of these previous studies (Schlegel *et al.*, 1967; Sparks and Hutchinson, 1980; Cornish *et al.*, 1999) point to various problems with articulation. These
problems are further classified as misarticulations, or as substitutions and omissions of sounds and “word endings”. But no details are given concerning these articulatory deficits. Recently, however, articulation of consonants in a group of Norwegian children with CDCS has been described in more detail, cf. Kristoffersen (2003b, 2004a). It was shown that all four subjects participating in these two studies had restricted consonant inventories compared to the target language, and that they had particular problems with laryngeal setting and with velopharyngeal function. Furthermore, they had problems with articulating lingual consonants, as compared to glottal and labial consonants, and with fricatives, as compared to plosives, nasals and approximants.

In Kristoffersen (2003a, 2004b) vowel productions of these subjects were described acoustically in terms of first and second formant frequencies. It was shown that there was considerable variation in different attempts at producing the same target vowels, but to a varying extent depending on both vowel height and quantity. Furthermore, there was considerable acoustic overlap between attempts at producing different target vowels. Finally, only to a limited extent did the vowel productions form vowel spaces comparable to the vowel space of the target language.

These previous studies of vowel and consonant articulation were purely descriptive, with no reference to an explanatory theoretical framework. In the present study various patterns of consonant production are analyzed in terms of articulatory phonology, a theoretical framework differing from most current phonological theories in treating articulatory gestures, and not features and segments, as basic. Articulatory phonology also differs from feature- and segment-based theories in focusing on temporal aspects of sound production.

From the perspective of Articulatory phonology, a given segment is a particular combination of the more basic articulatory gestures (Studdert-Kennedy and Goodell, 1995). Phonological words are described by gestural scores, which specify both the gestures constituting that word, and the way these gestures are coordinated. The speech of the subject of this study can be characterized by on the one hand numerous missing gestures, and on the other by wrongly coordinated gestures. This makes Articulatory phonology particularly suitable in this case. Weismer, Tjaden and Kent (1995) make a similar point for motor speech disorders, and Kent (1997) for neurogenic speech disorders and developmental phonological disorders. See also
Moen (2004) for an analysis of a case of foreign accent syndrome within this framework.

3. The subject

3.1 General development
The subject of this study, Hanna, has been raised in a monolingual Norwegian-speaking environment. She is a second child, and daughter of the author. She was diagnosed with CDCS when she was 6 weeks old. Diagnosis was suspected on the basis of her cry, and confirmed by chromosomal analysis, which showed a de novo terminal deletion with a breakpoint at 14.2.

Hanna received physiotherapy twice a week from she was 0;3 till she was 0;11. After that she has received physiotherapy on an irregular basis. She has been systematically taught sign language since she was 3 months old, mostly in kindergarten and school, but also to some extent at home. Since she was six years old she has attended a special class where signing is used regularly. She has received speech therapy regularly since she was 8 years old.

3.2 Linguistic abilities and linguistic development
Hanna understands spoken language relatively well. When she was 3;6, and again when she was 5;7, her language comprehension was measured with Reynell Developmental Language Scales (Reynell 1983). The results are displayed in table 3.

<table>
<thead>
<tr>
<th>Chronological age</th>
<th>Language age</th>
</tr>
</thead>
<tbody>
<tr>
<td>3;6</td>
<td>3</td>
</tr>
<tr>
<td>5;7</td>
<td>6</td>
</tr>
</tbody>
</table>

Hanna’s target language is Urban East Norwegian (UEN; cf. G. Kristoffersen, 2000). Table 1 shows the consonant phonemes of UEN word initially, word medially and word finally,¹ and table 4 shows the vowel phonemes in stressed syllables. Vowels in

¹ UEN has an apical r-sound /r/, whereas Hanna’s r, which first appeared when she was ca. 9, is uvular. Both r-types are represented in her family – her sister has an apical r, which is in accordance with her
unstressed syllables are always short. In addition to the short vowels in table 5, [ə] can appear in unstressed syllables.

Table 4
Consonant phonemes of Urban East Norwegian

<table>
<thead>
<tr>
<th></th>
<th>Word initial</th>
<th></th>
<th>Word medial</th>
<th></th>
<th>Word final</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab</td>
<td>Ap</td>
<td>Lam</td>
<td>Do</td>
<td>Glo</td>
<td>Lab</td>
<td>Ap</td>
</tr>
<tr>
<td>p</td>
<td>t</td>
<td>k</td>
<td>p</td>
<td>t</td>
<td>t</td>
<td>k</td>
</tr>
<tr>
<td>b</td>
<td>d</td>
<td>g</td>
<td>b</td>
<td>d</td>
<td>g</td>
<td>b</td>
</tr>
<tr>
<td>m</td>
<td>n</td>
<td></td>
<td>m</td>
<td>n</td>
<td>n</td>
<td>m</td>
</tr>
<tr>
<td>f</td>
<td>s</td>
<td>ç</td>
<td>h</td>
<td>f</td>
<td>s</td>
<td>ç</td>
</tr>
<tr>
<td>v</td>
<td>l</td>
<td>j</td>
<td>v</td>
<td>l</td>
<td>l</td>
<td>j</td>
</tr>
<tr>
<td>r</td>
<td></td>
<td></td>
<td>r</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t</td>
<td></td>
<td></td>
<td>t</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: The phonemes /p, t, k/ have two allophones, one aspirated and one unaspirated.

Table 5
Vowel phonemes of Urban East Norwegian

<table>
<thead>
<tr>
<th></th>
<th>Stressed syllables</th>
<th>Unstressed syllables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close</td>
<td>i, y, u, u</td>
<td>i, y, u, u</td>
</tr>
<tr>
<td>Mid</td>
<td>e, ø, o</td>
<td>e, ø, ø, o</td>
</tr>
<tr>
<td>Open</td>
<td>æ, a</td>
<td>æ, a</td>
</tr>
</tbody>
</table>

The development of Hanna’s consonant inventories from she was 4;6 till she was 7;0 has been described in Kristoffersen (2003b). In tables 6 – 9 three inventories from that study (from 4;6, 5;9 and 7;0) along with her inventory from 9;4 are presented. We see that all four inventories are restricted as compared to the inventory of the target language.

UEN variant. Hanna’s parents, who speak a southern and western dialect of Norwegian, have a uvular r. That Hanna’s r is uvular may be attributed to this variation, as well as the fact that uvular r-s are easier to pronounce than apical r-s.
Table 6  
**Consonant inventory at 4;6**

<table>
<thead>
<tr>
<th></th>
<th>Labial</th>
<th>Coronal</th>
<th>Dorsal</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plosive</td>
<td>p</td>
<td></td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td>n</td>
<td>ɳ</td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td>(υ)</td>
<td>(l), (l̃)</td>
<td>h</td>
<td></td>
</tr>
<tr>
<td>Approximant</td>
<td>l, (l̃)</td>
<td>j</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: In the tables showing consonant inventories phonetic symbols in parentheses represent marginal phones, i.e. sounds which occur only once or twice in the material (Grunwell 1985, 31).

Table 7  
**Consonant inventory at 5;9**

<table>
<thead>
<tr>
<th></th>
<th>Labial</th>
<th>Coronal</th>
<th>Dorsal</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plosive</td>
<td>(p̄)</td>
<td>t, t̄, (t̄)</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td>n</td>
<td>ɳ</td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td></td>
<td></td>
<td>h</td>
<td></td>
</tr>
<tr>
<td>Approximant</td>
<td>(υ)</td>
<td>l</td>
<td>j</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

Table 8  
**Consonant inventory at 7;0**

<table>
<thead>
<tr>
<th></th>
<th>Labial</th>
<th>Coronal</th>
<th>Dorsal</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plosive</td>
<td>p</td>
<td>t, t̄</td>
<td>k, (k̄)</td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td>n</td>
<td>ɳ</td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td></td>
<td>[OF̄]</td>
<td>h</td>
<td></td>
</tr>
<tr>
<td>Approximant</td>
<td>(υ)</td>
<td>l</td>
<td>j</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

Table 9  
**Consonant inventory at 9;4**

<table>
<thead>
<tr>
<th></th>
<th>Labial</th>
<th>Coronal</th>
<th>Dorsal</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plosive</td>
<td>p</td>
<td>t</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td>n</td>
<td>ɳ</td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td>f</td>
<td>[OF̄]</td>
<td>h</td>
<td></td>
</tr>
<tr>
<td>Approximant</td>
<td>v</td>
<td>l</td>
<td>j</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td>*))</td>
<td></td>
</tr>
</tbody>
</table>

A comparison with the consonant inventory of a typically developing boy acquiring Norwegian aged 2;5 further illustrates to what extent Hanna’s inventories are restricted, cf. table 10 (from Simonsen 1990).
Table 10

Consonant inventory of a typically developing boy aged 2;5 acquiring Norwegian

<table>
<thead>
<tr>
<th></th>
<th>Labial</th>
<th>Apical</th>
<th>Laminal</th>
<th>Dorsal</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plosive</td>
<td>p, pʰ, b</td>
<td>t, tʰ, d</td>
<td>t, tʰ, d</td>
<td>k, kʰ, g</td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td>n</td>
<td>n</td>
<td>η</td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td>f</td>
<td>ζ</td>
<td>η</td>
<td>s, s</td>
<td>h</td>
</tr>
<tr>
<td>Approximant</td>
<td>v</td>
<td>ι</td>
<td>δ</td>
<td>j</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>r, r, η</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We see that whereas this boy had a consonant inventory of 29 consonants at age 2;5, Hanna had 11 consonants at 4;6, 13 at 5;9, and 14 at 7;0 and 9;4.

Hanna’s speech at all four ages were furthermore characterized by excess of variability in articulations. Table 11 gives some examples.

Table 11

Variable pronunciations

<table>
<thead>
<tr>
<th>Age</th>
<th>Pronunciations</th>
</tr>
</thead>
<tbody>
<tr>
<td>4;6:</td>
<td>a. [kæ] and [ŋæ] for /tæŋ/ ‘pincers’</td>
</tr>
<tr>
<td></td>
<td>b. [kæ] and [ŋæ] for /stæjn/ ‘stone’</td>
</tr>
<tr>
<td></td>
<td>c. [mœ] and [nœ] for /kœn/ ‘clown’</td>
</tr>
<tr>
<td>5;9</td>
<td>a. [pæ] and [pœl] for /bæl/ ‘ball’</td>
</tr>
<tr>
<td></td>
<td>b. [ˈmilæ] and [ˈpilæ] for /briŋ/ ‘glasses’</td>
</tr>
<tr>
<td></td>
<td>c. [ˈutæ] and [ˈkutæ] for /bœte/ ‘bucket’</td>
</tr>
<tr>
<td>7;0</td>
<td>a. [ˈpitæ] and [ˈpiðæ] for /spisæ/ ‘eat’</td>
</tr>
<tr>
<td></td>
<td>b. [ˈupæ] and [ˈumæ] for /trœme/ ‘drum’</td>
</tr>
<tr>
<td></td>
<td>c. [ˈæpœl] and [ˈætɨθ] for /gœfl/ ‘fork’</td>
</tr>
<tr>
<td></td>
<td>d. [ˈlalæ] and [ˈnælæ] for /næjlæ/ ‘nails’</td>
</tr>
<tr>
<td>9;4</td>
<td>a. [ˈikæl] and [ˈsœukæl] for /sykl/ ‘bike’</td>
</tr>
<tr>
<td></td>
<td>b. [pɔˈlɔk], [pɔˈlœt] and [fɔˈlɔk] for /bɔmst/ ‘flower’</td>
</tr>
<tr>
<td></td>
<td>c. [ˈitæ] and [ˈitæ] for /stæxe/ ‘ladder’</td>
</tr>
<tr>
<td></td>
<td>d. [pajəˈpi] and [pajapil] for /pərəˈpræl/ ‘umbrella’</td>
</tr>
</tbody>
</table>
Among the variable pronunciations in table 11 we find omissions of segments (e.g. all items at 4;6 in table 11, item (b) and (c) at 7;0), cluster simplifications (e.g. item (b) at 5;9, item (b) at 7;0, and item (c) at 9;4), and various types of substitutions (e.g. item (c) at 5;9, item (c) at 7;0).

In spite of excessive articulatory variability at all four ages, there is also development in Hanna’s pronunciations towards more target-like words during the period covered by this study. In general, there is less variation, fewer omissions of segments, fewer cluster simplifications and fewer substitutions at 9;4 than at the preceding ages. A particularly good example of how her pronunciations have gradually grown more similar to the targets is her words for /æpəl/ ‘apple’:

4;6: [pæpæ]
5;9 and 7;0: [æpæ]
9;4: [æpələ]

At 4;6 there is a bisyllabic form where the voiceless bilabial plosive of the target word appears in the first syllable together with an open vowel, which shares the features front and unrounded with the root vowel of the target word. The bilabial consonant is copied along with the vowel onto the second syllable in Hanna’s form at 4;6. Also at 5;9 and 7;0 we find the voiceless bilabial stop of the target word, and again the vowel agrees in frontness and rounding with the root vowel of the target word. In Hanna’s words at 5;9 and 7;0, however, there is no copying of the consonant, only of the vowel. At 9;4 we find an epenthetic vowel between the two consonants in the target cluster – pəl–.

4. Method

Audio recordings made when Hanna was 4;6, 5;9, 7;0 and 9;4 make up the material for this study. At each of the four ages about 100 words were elicited, by means of a picture and object naming test developed on the basis of the author’s knowledge of Hanna’s production vocabulary. The same test – with a few minor variations – was
used at 4;6, 5;9 and 7;0. At 9;4 a more thoroughly revised test was used, which was more in accordance with her production vocabulary at that age.

Care was taken to avoid using the target words immediately before showing Hanna the pictures and objects included in the test material. Furthermore, to the extent it was possible, the pictures and objects were chosen so that all target phonemes in all positions in words were covered. In addition, items were included that elicited words with two place consonant clusters.\(^2\) All words were transcribed in IPA by the author.

At least two objections can be raised against this method of data collection (cf. Grunwell, 1985, chap. 2). First, speech samples containing spontaneous speech are normally considered better data than samples of speech elicited by a naming test. In this case, however, Hanna produced so few spontaneous utterances at all four ages that collecting spontaneous speech data would be infeasible. Furthermore, as her speech is heavily disordered, any attempt at recording spontaneous speech would run the risk of missing the intended meanings of her utterances.

A second objection concerns the size of the samples. Grunwell (1985, 7) considers a sample of 100 different words as a minimum, but recommends a sample twice as large, 'in order to obtain sufficient data to record the child’s realization of the majority of the adult targets more than once and thus to reveal the presence of any clinically significant variability […]'). Clearly, this is a reasonable recommendation. However, limitations in Hanna’s production vocabulary made it difficult to obtain even as many as 100 different words, not to mention twice as many. In addition, short attention span made it extremely difficult to obtain even the 100 different words that were elicited at each age.

5. Theoretical framework: Articulatory phonology

5.1. Articulatory gestures as phonological units

Articulatory phonology (AP) is a theory of the relationship between phonetics and phonology developed by Louis Goldstein and Catherine P. Browman and others (Browman and Goldstein, 1989, 1992; Byrd, 2003; Studdert-Kennedy and Goldstein,

\(^2\) Also three place consonants clusters are found in UEN, but since Hanna had no clusters at all at 4;6, 5;9 and 7;0, and no three place and only a few two place clusters at 9;4, items that aimed at eliciting three place clusters were not included in the material.
Within AP articulatory gestures are seen as basic phonological units. The term *gesture* refers to an abstract unit which represents a concrete movement by one or more articulators (lips, jaw, tongue tip, tongue body, velum, glottis).

Articulatory gestures can belong to three different subsystems of the vocal tract, the laryngeal, the velic and the oral subsystem, and they can be specified with respect to two sets of values, one designating constriction location (CL), and one designating constriction degree (CD) (Browman and Goldstein, 1989, 209):³

- Constriction location values: Protruded [lips], labial, dental, alveolar, post-alveolar, palatal, velar, uvular, pharyngeal
- Constriction degree values: Closed, critical, narrow, mid, wide

The terms *closed* and *critical⁴* correspond to the traditional terms *stop* and *fricative*, and the three terms *narrow, mid* and *wide* cover three height degrees for vowels. All the CL and CD values given above are relevant for the oral subsystem. For the velic subsystem there is a contrast between *wide* and unspecified. The value *wide* is attributed to nasal sounds. When no value is specified, in contrast, the sound in question is oral. In the laryngeal subsystem of the vocal tract a distinction is once more drawn between *wide* and unspecified: *wide* is attributed to voiceless sounds, whereas voiced sounds are unspecified.

5.2 Gestural scores
The phonological structure of an utterance is represented as a gestural score. A gestural score is a representation of the partly overlapping articulatory gestures that constitute the utterance. For example, the gestural score for the Norwegian word *mat* 'food’ is shown as figure 1.⁵

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³ Browman and Goldstein (1989:228f) briefly mention a third dimension, constriction shape (CS), to account for distinctions like apical vs laminal and central vs lateral. I return to the latter distinction below, in my analysis of example (3b)
⁴ Critical "indicates that critical degree of constriction for a gesture at which some particular aerodynamic consequences could obtain if there were appropriate air flow and muscular tension" (Browman and Goldstein 1989:225)
⁵ LIPS, TT (= tongue tip), TB (= tongue body), VEL (= velic aperture) and GLO (= glottalic) are names for tract variable sets. A tract variable set in the oral subsystem consists of a CL variable and a CD variable.
The first segment has a closed CD at the labial CL. At the same time, it is associated with a wide velic gesture, i.e. this part of the utterance is nasal. It is unspecified for a glottalic gesture. In other words, the segment in question is voiced. In more traditional terms, this part of the utterance is a labial nasal stop.

The next part of the utterance is the syllable nucleus, which has a wide CD at the pharyngeal CL – transcribed [ɑ:] in the score. There is still no value for the glottalic aperture at this point in the score, indicating that the vocal folds are still vibrating, and since it has no value for the velic subsystem, it is an oral segment.

The final part of the utterance, transcribed [t] in figure 1, is voiceless, as indicated by the value *wide* for the glottalic aperture. Moreover, it has a closed CD at the alveolar CL.

5.3. *Gestural 'errors’ in child language*

Browman and Goldstein (1989, 204f.) identify two stages in the development from children’s words to the corresponding target words. First, there is a stage of differentiation and tuning of individual gestures. When infants enter the stage of single word utterances (Ingram, 1989, 139ff.) they have a restricted set of speech sounds at their command. During the stage of differentiation and tuning, contrasts emerge which involve both constriction location (for example *dental vs. alveolar*) and constriction degree (for example *closed vs. critical*). One example of an emerging CL contrast is when the distinction in UEN between an apical and a palatal fricative [ʂ, ç] (cf. table 4 above) emerges from a stage at which only [ʂ] is used. And one example
of an emerging CD contrast is when children at one stage use [t] for both target [t] and target [s], and then at a subsequent stage come to differentiate between the two.

The second stage proposed by Browman and Goldstein (1989) is a stage of coordination of gestures. Even though infants and toddlers have a variety of articulatory gestures at their command, they have not yet mastered the often quite complex coordination of gestures that is necessary to produce target words. One example, from Studdert-Kennedy and Goodell’s (1995, 76) subject Emma, is the utterance [meː'nə] for the target word tomato. The gestural score for the target word is specified, among other things, for a sequence of an alveolar [t], a labial [m], and an alveolar [t] gesture in the oral subsystem. The second of these gestures is coordinated with the value wide in the velic subsystem, resulting in a nasal consonant. Emma’s attempt at this target word, [meː'nə], contains a labial and an alveolar gesture in the oral subsystem, and two wide gestures in the velic subsystem. The velic gestures are not properly coordinated with the oral gestures.

With respect to these two stages it is possible to identify various types of “errors” in both child language (cf. Studdert-Kennedy and Goodell, 1995, 81f.) and in disordered language (cf. Browman and Goldstein, 1992, 176 f.; Kent, 1997). I turn now to a discussion of the development of Hanna’s consonants in the perspective of errors of differentiation and tuning, and errors of coordination and sequencing. In addition, I discuss her speech development in terms of errors involving missing gestures.

6. Analysis

6.1. Errors of differentiation and tuning

Errors of differentiation and tuning can be of various kinds. Two important types are errors in constriction location and errors in constriction degree. (1) presents a couple of examples of the former type:

(1) a. ['katæ] for ['bɔtə] ‘bucket’ (5;9)
   b. ['lyθ] for ['lɪ:ʃ] ‘light’ (9;4)
In (1a) the initial segment in the target word has a labial CL; the corresponding segment in Hanna’s word has a velar CL. In (1b) the final segment in the target word is a fricative with an alveolar CL [s], whereas in the corresponding word produced by Hanna we find a fricative with a dental CL [θ].

Consider next three examples of errors involving constriction degree:

(2) a. ['nitæ] for ['nisa] ‘gnome’ (9;4)
   b. ['tæk] for ['sek] ‘backpack’ (9;4)
   c. [,vætɔi] for [,bætɔri:] ‘battery’ (7;0)

In both (2a and b) the alveolar fricative in the target word appears as an alveolar stop in the corresponding word produced by Hanna. In (2c) there is an error in constriction degree – labial approximant [v] instead of labial plosive [b] – in addition to an error in constriction location – labiodental instead of bilabial.

6.2. Errors of coordination and sequencing
In errors of gestural coordination the various gestures that constitute a target word are not properly coordinated, whereas errors of sequencing are errors where a gesture appears in the wrong place in a word. (3) gives a couple of examples from Hanna’s speech in which there is one or more errors of coordination and sequencing of gestures:

(3) a. ['mæ] for ['vʌn] ‘water’ (4;6)
   b. ['lɔn.æ] for ['nø.k] ‘key’ (7;0)

(3a) has a target word with two gestures in the oral subsystem, with labial and alveolar CLs. The second of these is accompanied by a wide velic gesture, producing the alveolar nasal consonant [n]. In Hanna’s word the velic gesture is wrongly combined with the labial gesture (with bilabial for labiodental CL), resulting in the word [mæ]. The target in (3b) is produced by a coordination of the following consonantal gestures: alveolar close [n], palatal mid [ɔ], velar close [k] and alveolar
close narrowed⁶ [l]. The first of these is combined with a wide velic gesture. Thus, all the gestures of the target word are present in Hanna’s reproduction of it. However, they are wrongly coordinated. In addition, there is an error of sequencing, in that the final [l] of the target word appears as the initial segment in Hanna’s word.

Another set of examples involving errors of coordination is shown in (4), where an epenthetic vowel appear between the two consonanats in a two place target consonant group:

(4) a. [pɔlɔt] for [bɾɒmst] ‘flower’ (9;4)
    b. [æpɔlɔ] for [eʰɾə] ‘apple’ (9;4)
    c. [θɔnænæ] for [fjæŋə] ‘snake’ (9;4)
    d. [pɔlɔ] for [bɾɔː] ‘blue’ (9;4)

In (4a) there is a sequence [pɔl] in Hanna’s word, which corresponds to a target sequence [bɾ]. In the target sequence the gestures making up the two consonants are coordinated in such a way that there is a certain overlap – the onset of the TT gesture for [ɾ] beginning before the offset of the LIPS gesture for [b]. In Hanna’s word, in contrast, the gestures for these two gestures are present, but they are not coordinated according to the “rules” of the target language, resulting in an epenthtic vowel. Similar analyses can be given to Hanna’s forms in (4b-d). Note than in all four examples the epenthetic vowel share one or more features with the root vowels.

6.3. Missing gestures

A third type of error, which does not fall properly within either of the two other categories, is concerned with gestures missing from an utterance. In the most extreme case all the gestures constituting a segment are missing, as in the following examples:

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⁶ The term *narrowed* refers to a value of constriction shape involved in the production of laterals. The aspect of laterals referred to is a “narrowing of the tongue volume, so that it is pulled away from the sides of the mouth (Browman and Goldstein, 1989,228; see also fn. 3 above.)
In (4a, b) all the gestures that constitute the lateral approximant of the target word are missing, and in (4c) all gestures constituting all consonants are missing. But the material also contains a number of words in which only some of the gestures constituting a segment are missing. Consider the examples in (6) – (7):

(6) a. [ˈhæ.næ] for [ˈtæj.nə] ’draw’ (4;6)
    b. [ˈhul] for [ˈfæːd] ’bird’ (9;4)
    c. [ˈhuθ] for [ˈdəuʃ] ’shower’ (9;4)

(7) a. [ˈpæ.tæ] for [ˈbæm.sæ] ’teddy bear’ (7;0)
    b. [ˈvi.tu.ə] for [ˈvɪn.duː.ə] ’window-the’ (9;4)

In (6) Hanna’s words contain a first segment corresponding to the first segment in the target words. However, this segment – pronounced [h] in all three cases – is only specified for a glottal gesture, and not for an oral gesture.

In the two examples in (7) both target words contain a sequence of an oral and a nasal consonant medially, that is, there is a wide velic gesture associated with the second consonant of this cluster. In Hanna’s reproductions, on the other hand, there is no wide velic gesture. In (7b) there is also a wrong CD value for the target [s], which is closed in Hanna’s word, instead of critical, as it should be.

To recapitulate, Hanna’s words can be characterised in terms of three different types of gestural deviations (or ”errors”) from target words. The first concerns errors of differentiation and tuning of gestures, the second concerns errors of coordination of gestures, and the third concerns missing gestures. All these errors contribute to her disordered speech, but, as I pointed out above, there is also clear improvement in many aspects of her speech during the period I have followed her development. I turn now to some important aspects of this development.
6.4. Developmental aspects

Hanna’s speech development can be regarded as a process during which she gradually gains control over her articulatory gestures. The following figures give the gestural scores for the target word *is* ’ice’ (figure 2), and for Hanna’s pronunciations of this word at 4;6 (figure 3), 5;9 (figure 4) and 7;0 and 9;4 (figure 5):

Figure 2
*Gestural score for the target word is ‘ice’*

![Diagram of gestural score for the target word is ‘ice’]

Figure 3
*Gestural score for Hanna’s pronunciation of is at 4;6*

![Diagram of gestural score for Hanna’s pronunciation of is at 4;6]
The target pronunciation (figure 2) is characterized by a palatal narrow vowel, and an alveolar critical consonant with wide glottal aperture. At 4;6 Hanna pronounced this word as [pi], cf. figure 3. Whereas this is certainly a strange reproduction in isolation, it is one of very many CV words in the material from 4;6. Furthermore, it has a vowel with the same CD and CL values as in the target words. The consonant corresponds to the consonant in the target word with respect to the value for glottal aperture, but has the wrong values for CD and CL within the oral subsystem. In addition, there is an error of sequencing of gestures in Hanna’s word, in that the consonant precedes the vowel, and not *vice versa* as is the case in the corresponding target word.

At 5;9 (figure 4) only the vowel is present, still with the same CL and CD values as in the target word. At 7;0 and 9;4 (figure 5) there is a higher degree of correspondence between Hanna’s words and the target word. The vowels have the
same values, the consonant has the same value for GLO and for TTCL. TTCD, on the other hand, is different: Where the target word has critical, Hanna’s word has closed.

Finally in this section I discuss some features of Hanna’s speech development in terms of articulatory phonology. In particular, I focus on the following question:

- Are Hanna’s forms (at one stage, or across stages), systematically good in some gestures and poor in others?

Consider again the consonant inventories in tables 3 – 6. First, remember that at 4;6 and 5;9 there are stops and nasals at three constriction locations, but no fricatives. At 7;0 the first fricative ([θ]) appears, and at 9;4 there are three ([f, θ, s]). This development suggests an improvement in Hanna’s ability to tune in on a particular constriction degree. Second, the variation in the coronal stop at 5;9 and 7;0 between dental/alveolar [t] and linguo-labial [t̪] suggests problems with the tuning of gestures, but this time related to constriction location. Again, there is improvement in that there is no variation at 9;4.

Another problem concerned with tuning of gestures in Hanna’s forms is related to the distinction in UEN between apical and laminal stops, nasals, fricatives and laterals, cf. table 1. At no age covered by this study Hanna makes such a distinction. In other words, in this case we find poor production and no improvement.

Thirdly, there are stops with nasal release at 5;9 and 7;0, indicating an inability to control the mechanism of the velic subsystem properly. At 9;4, on the other hand, there are no stops with nasal release. These facts may suggest an improvement. However, since there are very few stops with nasal release at 5;9 and 7;0, the fact that there are none at 9;4 does not strongly imply such an improvement.

There is also evidence for an improvement in the coordination and sequencing of gestures in Hanna’s forms, in particular in her productions of target consonant clusters. Consider again her various forms for the target word /ˈepəl/ ‘apple’:

(7)  

a. 4;6: [ˈpæpæ]  
b. 5;9 and 7;0: [ˈæpæ]  
c. 9;4: [ˈæpələ]
At 4;6, 5;9 and 7;0 only one of the consonantal gestures – labial closed – of the target word is present. Between 4;6 on the one hand and 5;9 and 7;0 on the other there is an improvement in sequencing in that there is no copying of gestures after 5;9. At 9;4 both consonantal gestures of the target word are present in Hanna’s word; in other words, there is improvement both in tuning and in coordination of gestures.

Concluding remarks

In this paper I have presented an analysis of consonant productions in one subject with cri cu chat syndrome within the framework of articulatory phonology. I have focused on various “error” types, where the term error refers to deviations from target productions. The subject’s consonant productions have been classified in terms of errors of differentiation and tuning, errors of coordination and sequencing, and missing gestures.

Furthermore, it was demonstrated, with reference to one particular word, how Hanna’s consonant productions became more target-like during the period covered by this study. Finally, I pointed out areas where Hanna’s forms showed improvement during the project period, and where there was no such improvement. In sum, there was improvement in her ability to control for both constriction degree, constriction location and velo-pharyngeal opening.

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References


