Consonant clusters in the speech of children with 5p deletion syndrome[1]

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Abstract

Due to motor problems and intellectual impairment, individuals with 5p deletion syndrome experience speech and language problems to varying degrees. This paper examines a corpus of spoken words and larger expressions uttered by eight children aged between four and twelve years with this syndrome, aiming to find out how they produce word initial consonant clusters in the target language.

Most of the children used the same strategies as younger, typically developing Norwegian speaking children to render the target clusters: omission, substitution and vowel intrusion. The most common strategy was omission, followed by substitution and vowel intrusion. In addition, some children also used preposed vowels and metathesis, and a few showed more idiosyncratic patterns, indicative of specific phonological problems.

Introduction

5p deletion syndrome is a rare genetic disorder resulting from a deletion of

1 Gjert has worked extensively with details of Norwegian prosody, including phonotactics and specific types of consonant clusters, e.g., Kristoffersen & Simonsen (2008; 2014). The present chapter is a contribution to this field from the perspective of clinical linguistics.

genetic material on the short arm of chromosome 5 with an estimated incidence between 1 in 15 000 births (Higurashi, Oda, Iijima, Iijima, Takeshita, Watanabe, & Woneyama, 1990) and 1 in 50 000 births (Niebuhr, 1978; Wu, Niebuhr, Yang, & Hansen, 2005). The clinical features of this syndrome, also known as Cri-du-chat syndrome, include a high-pitched cry in infancy and childhood, a short attention span, impaired fine and gross motor skills, mild-to-profound intellectual disability, and delayed speech and language development.

Many children with 5p deletion syndrome do not develop spoken language at all (Wilkins, Brown, & Wolf, 1980; Carlin, 1990; Cornish & Pigram, 1996; Dykens, Hodapp, & Finucane, 2000; Baird, Campbell, Ingram & Gomez, 2001). When they do develop spoken language, however, receptive language skills have been found to be significantly better than expressive language skills (Cornish & Munir, 1998).

Turning to phonetic and phonological skills, individuals with 5p deletion syndrome have been found to have small consonant inventories, a high proportion of incorrectly produced consonants, inaccuracy in realisation of target phonemes and variable similarity to target words. Several recurrent types of deviant consonants were observed, among which the most frequent were nasalised consonants and consonants with a lateral release (Kristoffersen, 2008; Kristoffersen, Garmann, & Simonsen, 2014). The most probable cause of the deviant consonants is impaired fine motor skills.

In typically developing (TD) children, mastering consonant clusters takes more time than mastering single consonants, and they use different strategies to produce target words with clusters before they produce them correctly. In this paper, we wish to investigate to what extent children with 5p deletion syndrome are similar to or different from TD children in this respect. We therefore start with an overview of the acquisition of clusters in TD children.

Studies of children's acquisition of consonant clusters across languages have shown that the most common pattern early in development is the omission of one of the consonants in a cluster (Bernhardt & Stemberger, 2018; McLeod, Van Doorn, & Reed, 2001a, 2001b). When the children master more consonants, they typically produce both elements in the cluster, but one or both may be non-target like. This is commonly called consonant substitution (Bernhardt & Stemberger, 2018; McLeod et al., 2001a, 2001b). A third pattern is vowel epenthesis or vowel intrusion, presupposing that both consonants in the cluster are produced in some way. Vowel intrusion is typically found in clusters with a liquid, and most in those with a rhotic (Bernhardt & Stemberger, 2018; Garmann, Simonsen, Hansen, Holm, Payne & Post, under revision; McLeod et al., 2001a, 2001b). Coalescence and metathesis are less common patterns, as well as the full omission of the consonant cluster, which is only found in the youngest typically developing (TD) children and in children with protracted development (Bernhardt & Stemberger, 2018; McLeod et al., 2001a, 2001b).

The main patterns can be exemplified by productions by the Norwegian TD boy Tomas at age 2;0. He pronounced the target word *trikk(en)* '(the) tram' [^{1}tɾic^h(ɛn)] with omission of the /r/ in [^{1}t^{h}ic^{h}ɛn], with substitution of the /r/ (and a long vowel) in [^{1}tði:c^h], and with vowel intrusion combined with substitution in [t^{h}i^{1}ɭic^h] (Simonsen, 1990).

Studies of word initial cluster acquisition in Norwegian have documented the same patterns as described above (Kristoffersen & Simonsen, 2006; Mehmet, Ben-David, Gerrits, Kristoffersen, & Simonsen, 2008; Simonsen, 1990; Vanvik, 1971). In addition, Garmann et al. (under revision) have shown that vowel intrusion is more common in Norwegian than in English. Bernhardt & Stemberger (2018) summarise a group of studies on children's productions of consonant clusters, saying that epenthesis (their term) was not found in Swedish and Icelandic, and that it was a relatively minor pattern in Spanish, Slovenian and Hungarian. However, adults' production patterns in the different languages must be taken into account. Garmann et al. (under revision) found that vowel intrusion was a relatively prominent phonetic feature of the production of word initial clusters by adults in Norwegian, but not in English. This may be ascribed to the fact that clusters in Norwegian have an open transition, meaning that there is an audible release of the first consonant before the closure of the second one, while clusters in English have a close transition, often with gestural overlap and no audible release of the first consonant in the cluster (Catford, 1988; Endresen, 1991). For the Norwegian adults, vowel intrusion was found in approximately 30 % of the targeted clusters; clearly most frequently in clusters with a liquid, in particular an /r/, as the second consonant, for example *grei* 'nice' pronounced [gəˈɾæj], and *brann* 'fire' pronounced [bəˈɾɑn].

Thus, in languages with an open transition between consonants in a cluster, vowel intrusion is not a mismatch pattern in the same way as the patterns of omission and substitution. This led Garmann et al. (under revision) to use the term vowel intrusion rather than epenthesis in line with the distinction between true phonological epenthesis (a categorical phenomenon) and phonetic vowel intrusion (a gradient and optional phenomenon) described in Hall (2006).

As indicated above, in Norwegian children all the three main simplification strategies mentioned above (omission, substitution and vowel intrusion) are found. The combined data from the three children in Simonsen (1990) across ten data-points between ages two and three (from 2;0 to 2;11) shows that overall 48 % of 243 instances of word initial clusters are produced correctly (ranging from 7 % for Nora at 2;3 to 79 % for Tomas at 2;9). Their cluster simplifications are distributed as follows: 49 % omissions of one consonant, 23 % substitutions and 24 % vowel intrusions, plus the minor strategy vowel prothesis (4 %). For all children omissions were prominent at the first age-points, but clearly diminishing with age; interestingly, vowel intrusions are found for all children at all age-points except one (Vera at 2;6). Insertion of a prothetic vowel was only found for two of the children, only at the earliest age-points, and often combined with omission, e.g. [ε^{2}mi:ɭεɾ] for *smiler* 'smiles', Nora 2;3). None of the children had full cluster deletion.

In a study of 27 TD Norwegian speaking children aged 21-36 months, Kristoffersen & Simonsen (2006) found that 78 % of 771 instances with initial two-consonant clusters were produced correctly. Of the remaining target clusters, one of the two consonants were deleted, either C1 (63 %) or C2 (37 %). Since vowel intrusion was not in focus in that study, no measures of this phenomenon were presented. However, we have unpublished data on vowel intrusion produced by these children, from two rounds of data collection, the first being the data set underlying Kristoffersen & Simonsen's (2006) study. Six of these children (aged between 23 and 34 months) produced one or more clusters with vowel intrusion. The length of these intrusions was between 60 and 160 ms.

The second set of data comprised attempts at clusters from 12 of the children from the first round, recorded about one year later. Two of the children, aged 38 and 43 months, produced clusters with vowel intrusions between 60 and 110 ms.

In a comparison between Norwegian and English data, with two-, four- and six-year-olds with three children in each group (Garmann et al., under revision), the Norwegian children produced respectively 0 %, 49 %, and 60 % of target words with a cluster correctly. That is, the older the children, the more correctly they produced the words with clusters. Even though the two-year-olds in this study did not have any correctly produced consonant clusters, the above data from Kristoffersen & Simonsen (2006) and Simonsen (1990) show that Norwegian two-year-olds manage to produce clusters correctly, although there is a lot of variation.

Figure 1 shows the distribution of omissions, substitutions and vowel intrusions in each age group (Garmann et al., under revision): Of the total number of productions, the two-year-olds had 22 % omissions, 59 % substitutions and 20 % intrusions, the four-year-olds had no omissions, 9 % substitutions and 42 % intrusions, and the six-year-olds had 4 % omissions, 11% substitutions and 25% intrusions. The developmental pattern of the younger children having more omissions, and the older having more substitutions fits with the developmental pattern of children acquiring other languages as reported in McLeod et al. (2001a). The vowel intrusions varied substantially in length, ranging from 8 to 162 ms, with a median of 43.

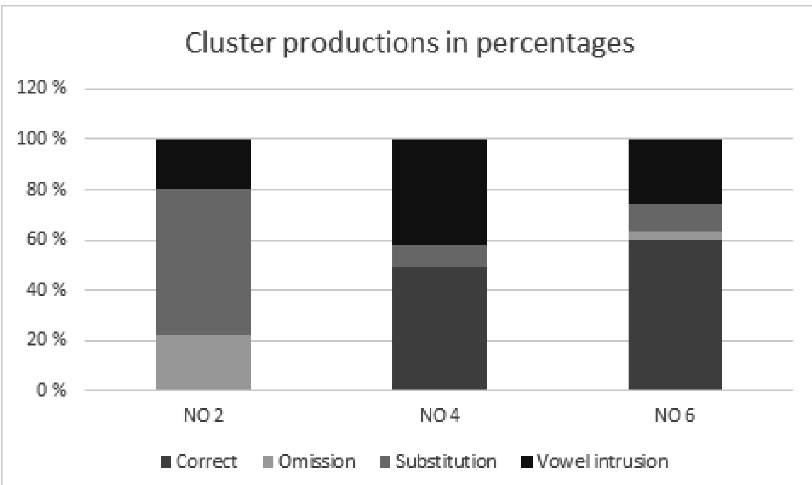

Figure 1: Cluster productions in TD children. Data from Garmann et al. (under revision).

Bernhardt & Stemberger (2018, p. 7) compare acquisition of word initial clusters with a liquid in children with protracted development and younger typically developed children, and find that these two groups show the same patterns.

Turning to phonetic and phonological skills in children with 5p deletion syndrome, we know from the relatively scarce literature that misarticulations and omissions are frequent (Cornish, Bramble, Munir, & Pigram, 1999; Kristoffersen, 2008; Kristoffersen, Garmann, & Simonsen, 2014; Schlegel et al., 1967; Sparks & Hutchinson, 1980). Furthermore, small consonant inventories compared to those of far younger TD children are common (Kristoffersen, 2008; Kristoffersen et al., 2014). Also, consonant inventories exhibited inter-subject variation both in number and type of consonants.

Focussing on misarticulations, Kristoffersen (2008) demonstrated in a longitudinal study of one girl with 5p deletion syndrome across the ages 4;6 to 9;4 that the Percent Consonants Correct measure (PCC-R) (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997; Shriberg & Kwiatkowski, 1982) varied from 22.8% to 69%, giving an indication of the magnitude of misarticulations. Kristoffersen analysed the misarticulations in terms of Articulatory Phonology, a model where the basic units of speech are taken to be concrete movements (gestures) by a combination of articulators, e.g., lips, jaw, tongue tip, body of the tongue, velum, or glottis (Browman & Goldstein, 1989, 1992; Byrd, 2003; Studdert-Kennedy & Goldstein, 2003). As an illustration, take the form [ˈlɔŋ.æ], for the target word *nøkkel* /ˈnø.kl̩/ 'key', produced by the single subject studied by Kristoffersen (2008). Based on a comparison of these two forms it was argued that most of the gestures making up the target pronunciation were also present in the child form, but in a different configuration. For example, the gesture represented by the lowered velum is present in both forms: in the target it is the onset of the first syllable; in the child form it is the coda of that syllable.

The results of Kristoffersen (2008) were confirmed in a more recent study of eight children by Kristoffersen et al. (2014). These subjects had low PCC-R values, small consonant inventories with several recurrent types of deviant consonants (relative to the target language), inaccuracy in the realisation of target phonemes and variable similarity to target words.

Garmann, Kristoffersen, and Simonsen (2018) examined the same data set as the one used by Kristoffersen et al. (2014) with reference to the theoretical concept of templates. Templates are generalisations over known words that are used to produce words that fit with the template (selection) or to change words that do not fit (adaptation) in order to facilitate memorisation, planning of production as well as actual production of new words (Vihman & Velleman, 2000). One example from the *Norwegian-Garmann* corpus on CHILDES (Garmann, Hansen, Kristoffersen, & Simonsen, 2019) is TD Iben (1;5) who uses the template LVCV, disyllabic words with an initial labial, in her early words. Some of her productions that fit with the template (selected words) are *mamma* 'mommy', *pappa* 'daddy' and *baby* 'baby', which she produces as in the target language. Her attempts to say *eple* 'apple' and *søpla* 'the garbage' on the other hand are adapted to this template, so she produces for example [ˈbɘla] for /^{2}eple/ and [pøˈlæjɘ] for /^{1}søpla/. Garmann et al. (2018) found that children with 5p deletion syndrome were able to generalise over words, and that some did that to a target like extent, whereas others generalised more than we would expect from TD children the same age. Taking H (4;6) as an example, she generalises heavily, and one prominent template is one of labial harmony (LVLV). She says [ˈpæpæ] in her productions of for example *pappa*, *baby*, but also for *eple*, *ape* 'ape' and *blad* 'magazine'.

Earlier studies of consonant production in children with 5p deletion syndrome have looked at single consonants. Since we know that consonant clusters are difficult for TD children, we are interested in investigating how children with 5p deletion syndrome cope with this challenge. We address the following research questions:

1. To what degree are the clusters produced by these children target like?
2. Do the children use the same simplification strategies as typically developing toddlers?

Our answers to these questions will be discussed with reference to the theoretical perspectives of word templates and Articulatory Phonology.

Method

Material and participants

Data for this study was drawn from the same source as was used in Kristoffersen et al. (2014) and Garmann et al. (2018). Single words and a few larger expressions produced by eight children aged between five and 12 years were collected by means of a naming test based on pictures and objects. The children were recruited through the Cri-du-chat family support group in Norway. Written informed consent was obtained from the children's parents, and the study was approved by the Norwegian Centre for Research Data, following standard procedures. Seven of the children grew up in monolingual Norwegian-speaking families. One, child C, grew up in a Swedish-Norwegian bilingual family.

The naming test aimed at capturing all single consonants in all word positions and most initial consonant cluster productions in Norwegian. However, the items in the test had to be tailored to the individual child due to extensive variation in cognitive and linguistic skills. Accordingly, the children produced a variable number of words, ranging between 37 and 154. In addition, some of them also produced a few spontaneous multi-word utterances during the test session, enabling us to categorise their typical utterances into one-word or multi-word utterances. Table 1 sums up these characteristics for each child.[2]

Table 1. Participants' age, gender, total number of words produced, utterance type in conversation, and intelligibility rating

Participant	Age	Gender	Total number of words produced	Utterance type (in conversation)	Intelligibility rating
A	6	F	91	Multi-word	High
B	6	F	110	Multi-word	Medium
C	5	F	147	Multi-word	Medium
D	12	F	37	One-word	Low
E	10	F	135	Multi-word	Low
F	10	M	97	One-word	Low
G	9	M	61	One-word	Low
H	9	F	154	Multi-word	Low

2 The intelligibility ratings were made by the third author based on all the children's utterances during the data collection.

Seven of the eight children (A-G) were seen only once. The last child (H) was followed over a longer period, with data collected at 4;6, 5;9, 7;2, and 9;4. As part of the results we present her attempts at consonant clusters at each of these stages, as they provide a good illustration of how production of consonant clusters develops over time in a child with this syndrome. In our analyses, we have taken into consideration that the children's target dialects varied somewhat. Relevant for this study is in particular the rhotics (apical vs. uvular) and presence vs. absence of apical sounds.

Data analysis

For all the children, we selected their attempts at rendering target words with an initial two-consonant cluster. First, we excluded all imitations. Then, inflected forms were considered to be separate target words, so for example we kept for analysis productions of both *brun* ('brown' adj. m. sg.) and *brunt* (n. sg.) (example from subject E). For some of the children, we recorded more than one attempt at target words. We then picked out the forms that varied in the way the consonant cluster was produced. For example, subject B made two attempts at *sko* 'shoe': [s̪k̪ˡu] and [æsku], and two attempts at *snegle* 'snail' [slæjlə] and [səlɛlə]. In both these cases, the initial consonant clusters are produced differently, and therefore, we kept both productions in our data set. We did not, however, keep all of the productions of for example the name *Kristin* by subject G. Even though some of the productions varied in word length, as [ŋikə] and [ŋæ], we only kept one of these variants since they do not vary in the way the initial consonant cluster is produced.

We also ignored phonetic variation that we considered irrelevant to the focus of the study: First, vowel length was not taken into account (and is not marked in our transcriptions). Second, variation in voicing was not reckoned as relevant, and we counted only one of the words if they only varied in voicing, as in some of G's productions of *blå* 'blue': [mbɔ̃] and [mpɔ]. Third, glottal consonants were not counted as consonant productions unless they were part of the target word. Accordingly, [ˈhʉ] for *brus* [^{1}brʉ:s] 'soda' by subject H (4;6) is reckoned as an instance of full omission. This reduced our data set from 300 forms to 271 forms.

We have used the following categories in our analysis: Correct, Full omission, Partial omission, Substitution, Omission + substitution, Vowel intrusion, Vowel intrusion + substitution, Metathesis, Prothesis, Prothesis + omission, and Other.

The category Other was established because a number of instances were not easily categorised in terms of the conventional analytic categories. We will return to the characteristics of the members of this category below.

Results

We first present the results from the cross-sectional data of the eight children, summarised in table 2.

Table 2. Attempts at consonant cluster production, overview of all children

Participant	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Total**
% correct of own productions	68	53	14	10	27	0	0	16	
Correct	17	17	3	1	7			5	50
Full omission						21		4	25
Partial omission	6	1	9	6	6		1	17	46
Substitution	2	7	3		11				23
Omission + substitution			4	3					7
Vowel intrusion		1			1			4	6
Vowel int. + substitution		3			1			1	5
Metathesis			1						1
Prothesis		1							1
Prothesis + omission		1							1
Other		1	2			3	10		16
Total	25	32	22	10	26	24	11	31	175

Table 2 shows that there is huge variation between the children. They produce between 10 and 32 words with word initial consonant clusters. The correct productions are mainly carried by subjects A and B: A has 68 %

correct productions, and B has 53 %. F and G have no correct productions, while subjects D, C, H and E vary between 10 % and 27 %.

The most frequent simplification strategy, found in all eight children, is omission, with partial omission as the most frequent type, but also a fair amount of full omission; less frequent subtypes are omission + substitution, and prothesis + omission. The second most frequent strategy is substitutions (including substitution alone, omission + substitution, and vowel intrusion + substitution), found in all children except F and G. In three children, B, E, and H, vowel intrusion is also found, either alone or in combination with substitution.

Quite a few of the consonant cluster productions were difficult to place under any of the main categories above. These are categorised as "Other", and as shown in table 2, they are only found in B, C, F and G, where G produces the majority.

The productions of F were difficult to analyse in the above categories because most of his productions do not contain oral consonants. He does produce some glottal stops and glottal fricatives, but it is difficult to decide whether they are to be considered as substitutions for true consonants, or simply a result of respiratory activity involved in speech (see also Kristoffersen et al., 2014), e.g. [ʊ.ʔʊ] for *traktor* 'tractor', [hi] for *kniv* 'knife'; [ʊ.æ] or [ʔʊ.ʔa] for *blomster* 'flowers'. Accordingly, as explained in the section on data analysis above, most of his productions are counted as full omissions as the glottal consonants are not considered true consonants. In his three instances of "Other" (*grå* 'grey' [pɔl]; *klokke* 'watch' [wa]; *krone* 'crown' [ŋʊ̃.ʔa]) only some of the vowels are indicative of the target word. In *krone*, we see that he has picked up on the nasality of the n, but the velum is lowered across the first syllable instead of the second syllable.

In contrast to F, G produces consonants, and occasionally something that appears to be consonant clusters, but his productions are difficult to analyse in terms of individual segments. Rather, his productions are quite templatic, involving reduplications, backing and nasalisations (see also Kristoffersen et al., 2014; Garmann et al., 2018), e.g. [ŋgæŋgæ] for *Kristin* [^{2}cristin] (name) and [ŋgɔ̃xɔ̃] for *skole* [^{2}sku:le] 'school'.

C has a few instances in the "Other" category which can be characterised as templatic as well as affected by lateralisation: It is possible to recognise aspects of elements in the target cluster, but they are distributed across the word, in a manner that defies categorisation in segmental terms, e.g. [ˈpupa] for *strympor* 'socks', [ˈudlala] for *stövlar* 'boots', and [ˈdʊdla] for *tröya* 'singlet'.

At the other end of the scale, A and B have relatively similar proportions of consonant clusters produced correctly. However, A has a large proportion of partial omissions, and only a few substitutions, whereas B has a large proportion of substitutions as well as showing a wide range of the other simplification strategies. A uses two simplification strategies: 6 partial omissions and 2 substitutions. All her partial omissions are omission of /s/ in s-clusters. B has 9 substitutions of /r/ (e.g. [tlatu] for *traktor* 'tractor', [tjɛkant] for *trekant* 'triangle' and [kəˈðunɛ] for *krone* 'crown') and 2 of /n/ (both replaced by /l/, e.g. [slæjlə] for *snegle* 'snail'). Together with subjects H and E, subject B has vowel intrusions (5, 2 and 4 respectively), and she and subject H are the only ones producing consonant clusters with prothesis (2 each). These strategies are also found in TD Norwegian children (Simonsen, 1990; Kristoffersen & Simonsen, 2006).

D produces few (only 10) target words with initial consonant clusters, and only one of these is produced with the correct consonant cluster: [ˈflɑʔg] *flagg* 'flag'. As for the rest, she omits the /s/ in s-clusters and the second consonant in the remaining clusters, producing [ˈmøl] for *smør* 'butter' and [ˈbʉs] for *brus* 'soda water', twice also substituting /b/ with /d/ and /k/ with /t/, as in [ˈdo] for *blå* 'blue' and [ˈtotɑn] for *klokke* 'watch'. Again, this is similar to what younger TD children do (Kristoffersen & Simonsen, 2006).

In her 26 target words with clusters, E produces 7 of them with the correct consonants: e.g. [flʉə] for *flue* 'fly'. In about the same number of clusters one of the consonants is omitted, as in [cˡu] for *sko* 'shoe' and [pædə] for *spade* 'shovel' in the same manner as D. Her main simplification strategy is substitution, where she fronts her dorsal consonants, e.g. [tˡotə] for *klokke* 'watch', and she often substitutes the /r/ with an /l/, e.g. [plik] for *prikk* 'dot'. Additionally, she has two instances of vowel intrusion, as in [fəlacˡ] for *flagg* 'flag'. As illustrated in some of the examples above, she also has a lateral release in many of her consonants, also outside of the clusters.

Subject H produces many (31) target words with initial clusters, and 5 of them are produced correctly, all of them produced as [kʀ]: [kʀɵnæ] for *krone* 'crown' and [kʀɔ] for *grå* 'grey'. Her dominant strategy is full or partial omission, with full omission in 4 instances, for example [ikæ] for *stige* ‘ladder’. She has 17 instances of partial omission, sometimes omitting the first consonant, as in [titæ] for *stige* ‘ladder’, [niʊ] for *kniv* ‘knife’ and [læk] for *glass* ‘glass’, as well as omitting the second consonant in words like [patæ] for *plaster* ‘band aid’. Except for /s/, the omission of the first or second consonant is unsystematic. She also produces some of her clusters with vowel intrusion, as in [pɔlɔ] in *blå* ‘blue’, [θəlaŋæ] for *slange* ‘snake’, and [fælæk] for *flagg* ‘flag’. Note that the vowel is sometimes a schwa and sometimes a copy of the following lexical vowel.

We now turn to the longitudinal data of subject H. As noted above, subjects A to G were seen only once, whereas subject H was seen four times, when she was 4;6, 5;9, 7;0 and 9;4. Table 3 presents an overview of her attempts at target clusters at all four data points.

Table 3. Attempts at consonant cluster production, subject H longitudinal data

	4;6	**5;9**	**7;0**	**9;4**	**Total**
% correct of own productions	0	0	0	16	
Correct				5	5
Omission (full)	12	18	16	4	50
Omission	6	7	17	17	47
Omission + Substitution	9	4	1		14
Vowel intrusion				4	4
Vowel int.+Substitution				1	1
Total	27	29	34	31	121

We see that subject H has very few correct attempts at initial clusters. In fact, we find her first correct productions only at the age of 9;4. The two most frequent simplification strategies are full omission and partial omission. Over time the distribution between them changes: At 4;6 and 5;9 full omissions dominate, at 7;0 they are relatively similar in numbers, while at 9;4 full omissions diminish and partial omissions are the most frequent. Note also that the vowel intrusions occur only at 9;4, when she starts producing two consonants in the cluster – this happens at the same time as the first correct attempts at initial clusters.

At the first age-point, H produces the correct number of syllables, nearly correct vowels but the consonants are either omitted or substituted. However, her templatic constructions make it difficult to use these terms to characterise her productions: She overuses a few patterns, for example [pæpæ] for *blad* 'comic magazine', *blomster* 'flower', and *spade* 'shovel', and [alæ] for *bleie* 'diaper', *briller* 'glasses', and *fjellet* 'the mountain'. In Garmann et al. (2018) these productions were analysed in terms of templates, indicating that her word representations are more advanced than her articulatory production. The above forms show that she picks up some of the gestures in the words, and produces them, although not necessarily in the right position in the word. The same can be seen in words with nasals, for example she says [næ] for *grønn* 'green', *klovn* 'clown', and *stein* 'stone'.

Her development is very slow, but a major change is seen at age 9;4. First, the number of omissions is reduced considerably. At the same time, correct productions appear for the first time, with 16 % correct productions. Third, vowel intrusions appear along with the production of two consonants in the cluster.

Discussion

As we have demonstrated in previous studies of these children with 5p deletion syndrome (Kristoffersen et al., 2014; Garmann et al., 2018), there is huge variation in their language skills, and the analyses of the children's consonant cluster productions confirm this. Largely, they use the same simplification strategies as typically developing Norwegian children, showing that in this respect they are delayed but not deviant. However, many of them have additional phonological characteristics, e.g. nasalisation and lateral release, which make their speech more difficult to understand. Moreover, the phonology of subjects F and G is so rudimentary that it is difficult to say whether their language development should be characterised as deviant or delayed.

We have addressed two research questions in this study. The first was to which degree their word initial cluster productions are target like. We found considerable variation in this respect: Subjects A and B are target like in more than half of their productions, while the other children have between 10 and 27 % target like productions (C, D, E, H), or none at all (F and G). Compared to the TD children in Garmann et al. (under revision), A has a similar rate of correct productions as TD six-year-olds (matching her chronological age), B is similar to TD four-year-olds (a delay of two years), the rest are below this percentage.

To what degree do correctly produced clusters relate to intelligibility? Intelligibility seems to correlate with the degree of correctly produced consonant clusters in all our subjects, except for C and E. Subject C has a relatively low percentage of correct clusters (14 %), still her intelligibility is rated as “medium”. This may be explained by her simplification strategies being similar to those of TD children, which may contribute to the listeners’ comprehension. Subject E, on the other hand, has a higher percentage of correct cluster productions (27 %), but her intelligibility is even so rated as “low”. In words with a consonant cluster, she shows a lot of lateralization, fronting of dorsals as well as occasional nasalization and stopping of fricatives, which in combination may contribute to low intelligibility (see also Kristoffersen et al., 2014).

The second research question was whether the participating children use the same strategies as TD toddlers. Mostly, the children in our study use the same simplification strategies as are found in TD children: Partial omission, substitution of one of the consonants, and vowel intrusion (as well as occasional cases of prothesis). In TD children, partial omission is generally a dominant strategy before substitution takes over later in development. For most of the children in our study, partial omission is more prominent than substitution, indicating an early stage of cluster development. There are some exceptions: A, who matches TD six-year-olds in correct productions, still has partial omissions as her main error strategy.

Looking in detail at H’s development from 4;6 to 9;4, we see that while she is clearly delayed with a protracted development, her strategies follow the same pattern as TD children in their development: Full omissions are dominant at the beginning, gradually partial omissions take over, and finally when she manages to produce two consonants in a cluster, correct productions as well as vowel intrusions appear.

However, most of these children also show some deviant patterns: Full omission is prominent in F and H, a pattern that is not found in TD children above 2 years (but documented for very young TD children, and for children with protracted development (Bernhardt & Stemberger, 2018; McLeod et al., 2001a, 2001b)). G’s productions are highly templatic, with extensive nasalisation, which makes them difficult to analyse in segmental terms. Several of the children in the study (B, C, E, H) also show lateralisation to different degrees – this process is not found in TD children (and is a general articulatory process not related to consonant clusters per se).

Three of the children (B, E and H) show the characteristic Norwegian pattern of vowel intrusion. All of the intrusions are found in clusters with liquids in the target words, except one, where the subject substitutes a nasal with a liquid /l/, when B says [səlɛlə] for *snegle* 'snail'. This pattern is similar to what is found both for adults and TD children, and cannot be seen as an error pattern since this is the way Norwegian is spoken, being a language with an open transition. The fact that this pattern is used indicates that those children have an ear for fine phonetic detail in Norwegian phonology, and that their perception possibly is more advanced than their production.

Articulatory Phonology gives an illustrative explanation of vowel intrusion in clusters: When the consonantal gestures in a cluster do not overlap, which is the case in languages with an open transition, a default vowel gesture emerges between them (Browman & Goldstein, 1991, p. 371). This vowel gesture may reflect a neutral tongue configuration, resulting in a schwa, like in the above example from B: [səlɛlə] for *snegle* 'snail'. In other cases, the intrusive vowel is similar to the lexical vowel, e.g. H's [pɔlɔt] for *blomst* 'flower' and [fælæk] for *flagg* 'flag', indicating an anticipatory vowel gesture configuration (and not a copying of the lexical vowel). Similar variation is also found in TD children (Garmann et al., under revision).

As indicated above, the productions of some of these children (F, G, and H) are not well described or explained in segmental terms (e.g. as omissions or substitutions), but rather in terms of a few general word patterns or templates. For example, many of H's productions at 4;6 belong to a few word patterns, indicating that her articulatory repertoire is still small, while her perception of the words is better, indicated by the fact that her vowels are closer to the targets. The same applies to the productions of F and G. In G, an additional lack of control of the velum results in patterns with extensive nasalisation.

Articulatory Phonology, with its focus on separable gestures across the word, also seems to be a useful model for explaining some of the deviant, non-target-like productions of the children in our study, when categorisations like omissions or substitutions do not really work. For example, in F's attempt at producing *krone* 'crown': [ŋʊ̃.ʔa] (one of his few examples of a word with oral consonants), the dorsal closure for the /k/ is in place, while the lowered velum for the /n/ is there, but spread across the first syllable instead of placed in the onset of the second syllable. And in H's (7;0) attempt at *blad* 'comic magazine': [pæl], the labial gesture is in place, while the lateral closure gesture is moved to the end of the syllable. Again, the articulatory control in coordination of the gestures is more difficult for her than the perception of the phonological target.

To sum up: The children with 5p deletion syndrome in this study show huge variation in their ability to produce initial consonant clusters. Most of the children exhibit the same simplification strategies (omission, substitution, vowel intrusion and (occasionally) prothesis) as found in TD Norwegian-speaking children, and in this respect their development can be seen as delayed. However, many of them show additional strategies or patterns that are more deviant. Full omission of the cluster is not found in TD toddlers; some of the children have an extensive use of a few templates in their productions for their age, and for many lateral release and nasalisation are prominent traits. Altogether, our results indicate – in line with earlier studies – that for most of these children their perception is better than their articulatory control, and that for many of them models using templates and/or Articulatory Phonology give a better description of their emerging phonologies than other, more segment-based approaches.

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