Article:

Yavas, M., Fox-Boyer, A.V. and Schaefer, B. orcid.org/0000-0002-0531-1348 (2018) Patterns in German /ʃC/-cluster acquisition. Clinical Linguistics & Phonetics, 32 (10). pp. 913-931. ISSN 0269-9206

https://doi.org/10.1080/02699206.2018.1469670

Patterns in German /ʃC/-cluster acquisition

Mehmet Yavaș
Florida International University
Miami, FL

Annette Fox-Boyer
European University of Applied Sciences
Rostock, Germany

Blanca Schaefer
University of Sheffield, UK

Address for correspondence:
Mehmet Yavaș
Florida International University
Linguistics Program
Miami, FL, USA 33199
e-mail: yavasm@fiu.edu
Fax: 305-348-3878

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Abstract

This study reports on the developmental patterns of /ʃC/ clusters in 145 normally developing monolingual German-speaking children between 2;00-2;11. All children completed a picture naming task to allow a systematic qualitative analysis of the production patterns. Children's reductions of target /ʃC/-clusters are examined and are evaluated with respect to two models, 'factorial typology' and 'headedness', to account for them. The results reveal expected patterns of C2 retention for '/ʃ/+[-continuant]' (e.g. '/ʃ/+stop' and '/ʃ/+nasal') targets, and a rather indeterminate pattern for /ʃl/ and /ʃʁ/. The results for /ʃv/, a clear-cut preference of C2 retention, were rather unexpected, as the C2 is a [+continuant]. The explanation offered for the retention of /v/ is related to a place constraint. The study also examines the data from children who reached an advanced stage of cluster formation with differential targets. More specifically, in several children, one target, /ʃv/, is found to have stayed behind in the reduction phase while all others have advanced to the 'cluster stage'. Neither the type nor the token frequencies seem satisfactory in accounting for the specific behavior of /ʃv/. The explanation offered for the uniqueness of this target may be its non-abidence to the SSP (Sonority Sequencing Principle) because of its flat sonority and the Obligatory Contour Principle (OCP) [continuant], because of the unchanging 'continuance' which is demanded by the OCP. Theoretical and clinical implications are discussed.

Keywords: consonant clusters, German, ʃC clusters, 2-year olds, toddlers

Introduction

It is typical in cross-linguistic acquisition patterns, when children are not able to produce two-member clusters accurately, for the most common process to be reduction of the target to one member[1]. In this paper, we examine the reduction patterns of ʃC clusters in German speaking children, aged 2-3 years. We begin our exposition with the structural idiosyncracies of s/ʃ+C clusters in languages. This is followed with the cross-linguistic findings on these clusters, with emphasis on children's cluster reduction patterns and the approaches to account for these. The data from German-speaking children are examined next, followed by the results and discussion.

<u>Linguistic characteristics of s/ʃC clusters</u>

Since there are considerable commonalities between German ʃC clusters and sC clusters found in several languages, we begin our discussion with the latter. The behavior of /s+stop/ clusters in contrast with other clusters has been part of the overall curiosity about the oddities of sC clusters in general. By dropping the sonority level from C1 (/s/) to C2, /s+stop/ clusters violate the Sonority Sequencing Principle (hereafter SSP), which requires that the nucleus of the syllable (the sonority peak) is preceded and/or followed by a sequence of segments with progressively increasing/decreasing sonority (Clements, 1990). German /ʃ+stop/ (/ʃp, ʃt/) clusters similarly violate the SSP, as in Spinne [ʃpɪnə] 'spider', and Stuhl [ʃtul] 'chair', whereby sonority falls, instead of rises, from the first member of the cluster to the second.

Although other sC clusters (e.g. /sm, sn, sl, sw/) follow the SSP by increasing the sonority from C1 to C2, they display other peculiarities. For example, in English, sC clusters violate the principle that disallows homorganic clusters (e.g. /pw/, /bw/, /tl/, /dl/ are prohibited): /s/ can co-occur with other coronals, as in /st/, /sl/, /sn/). In similar fashion, ʃC clusters (i.e., /ʃ + sonorant C/) in German violate the constraint Obligatory Contour Principle (hereafter OCP). These clusters have the same articulator and hence do not show place identity effects, as shown in Schlange [ʃlaŋə] "snake" and Schnecke [ʃnɛkə] "slug", whereby both members are [+coronal].

English sC clusters are also different from other clusters in that they violate the generalisation that prohibits 'obstruent + obstruent' clusters (e.g. /pt/, /fk/ are prohibited): /st/, /sk/ are allowed. German follows suit with some ʃC clusters (ʃp, ʃt, ʃv), as shown in Spinne [ʃpɪnə] 'spider', Stempel [ʃtɛmpəl] 'stamp', and Schwein [ʃvaɪn] 'pig'.

Finally, in English, 'obstruent + nasal' onsets are only found in sC clusters: e.g. /sm/ and /sn/ are permissible, but there are no other onsets where C2 is a nasal. German ʃC clusters show similarities in this respect. With the exception of a dorsal stop C1 (e.g. Knabe [knabɛ] 'boy'), only ʃC clusters allow nasals as C2, as shown in schmutzig [ʃmʊtsik] 'dirty', and schnell [ʃnɛl] 'quick'.

The acquisition of sC and ʃC clusters

There is considerable literature on the acquisition of sC clusters in several languages such as English (Yavaș & Core, 2006; Yavaș & McLeod, 2010), Dutch (Gerrits & Zumach, 2006; Gerrits, 2010), Norwegian (Kristoffersen & Simonsen, 2006), Croatian (Mildner & Tomic, 2010), Polish, (Yavaș & Marecka, 2014), Hebrew (Ben-David, 2006; Ben-David, Ezrati & Stulman, 2010) and Greek (Yavaș & Babatsouli, 2016), to name a few.

In addition to the structural idiosyncracies mentioned above, the #sC clusters in question seem to behave differently from other clusters in acquisition. Barlow (2001) suggests that some developing grammars are better explained by appealing to a different (adjunct) status of sC clusters in English. Some scholars (Grunwell 1981; Smit, 1993) state that some children's erroneous productions of sC clusters seem to be independent of the productions of other clusters. There are also suggestions that, in some children, sC clusters emerge earlier than other clusters (Smit, 1993; Gierut, 1999). Studies in German ʃC clusters echo the different behavior: Elsen (1991) suggests that ʃC clusters are acquired later than other clusters. Ott, van de Vijver & Hohle (2006) state that ʃC clusters behave differently in the language acquisition of children with delayed phonological acquisition. However, a more recent study (Schaefer & Fox-Boyer, 2017) showed that ʃC clusters were acquired at a similar age to other clusters in German-speaking children when fronting of /ʃ/ → [s] or backing of /ʃ/→ [ç] was accepted.

The above phenomena have led scholars to suggest a special 'adjunct' status for s/ʃC clusters. According to their proposal, the /s/ of the clusters is a direct dependent of the syllable, rather than being syllabified directly under the onset position (Si-Taek, 1992; Wiese, 1996). Consequently, this creates two categories of cluster types: 'true clusters' (complex onsets) referring to canonical obstruent + liquid clusters, and 'adjunct clusters', referring to #sC clusters. This suggestion for sC structures has also been made for other languages (Steriade, 1988 for Greek, Davis, 1990 for Italian, Trommolen 1984, and Fikkert, 1994 for Dutch). The two categories of cluster types are shown in figure 1.

Insert figure 1 about here

While the English extrasyllabic /s/ is to be linked to the syllable node, in German, /ʃ/ will have to be linked to the PWd (prosodic word), because, although these clusters occur stem-initially, they do not occur morpheme-internally (Hall, 1992). This is given in figure 2.

Insert figure 2 about here

While the separation of true clusters (e.g. /pl/, /gr/, etc.) from negative-sonority 's/ʃ +stop' clusters is rather uncontroversial, the status of different combinations within the s/ʃ cluster group has been rather contentious. In L1 acquisition studies, some scholars have argued that all /sC/ clusters are 'adjunct' clusters (Trommolen 1984; Kager and Zonneveld 1986 on Dutch; Davis 1990 on Italian, Barlow 2001 on English, Goad & Rose, 2004 on German), whereas other researchers have treated only certain subgroups of sC clusters as adjuncts. Fikkert (1994) considers only sonority-lowering Dutch /s+stop/ (hereafter /sT/) clusters and Hall (1992) only non-sonority rising ʃC clusters of German as adjuncts, while Gierut (1999) also includes /s+nasal/ clusters in English (hereafter /sN/) in this group[2].

Studies on typically developing English-speaking children (Yavaș & Core, 2006) and children with phonological disorders (Yavaș & McLeod, 2010) show that clusters with /sl/ and /sw/ targets (i.e., /s/ + [+continuant]/) developing significantly earlier than /s+stop/ and /s+nasal/ (i.e., /s+[-continuant]) targets. This is especially true for /#sw/ targets. Several children show cluster production for this target while remaining at the reduction stage for the others. However, studies on other languages such as Hebrew (Ben-David, 2006; Ben-David, Ezrati & Stulman, 2010), Dutch (Gerrits & Zumach, 2006; Gerrits, 2010), Norwegian (Kristoffersen & Simonsen, 2006), and Croatian (Mildner & Tomic, 2010) do not show any such preferences.

Linguistic principles of cluster reductions

As shown in numerous acquisition studies, when children are not able to produce two-member consonant clusters accurately, the most common process is to reduce the target cluster to one member. Typically, in these cases, the most sonorous element is deleted. This is explained in terms of the resulting form providing a higher jump in sonority from the retained least sonorous segment to the higher sonority nucleus. This is in accordance with the Sonority Dispersion Principle (Clements, 1990), which states that the sharper the rise in sonority between the beginning of the syllable and the nucleus, the better the syllable. For example, the following realisations please [pliz] → [piz], print [prɪnt] → [pɪnt], black [blæk] → [bæk], broom [brum] → [bum] are commonplace because the resulting forms reveal sharper rises from the onset to the nucleus. On the other hand, the alternatives [liz], [rɪnt], [læk], [rum], whereby the less sonorous member of the cluster is eliminated, are not found in typical development for English. This pattern is also applicable to some sC clusters; for example, the reductions observed for target /s+stop/ clusters is the retention of C2, as in stop [stɑp] → [tɑp] (i.e., lower sonority 'stop' rather than C1 retention, [stɑp]→[sɑp]). However, when it comes to /s/+ sonorant C targets (especially when C2 is an approximant), literature shows two possible patterns: retention of C1 (Smit, 1973) or C2 (Gnanadesikan, 2004; Ohala 1999). If the sonorant C2 is a nasal, however, the predominant pattern is to retain the nasal (e.g. snake [snek] → [nek]), which is clearly against the principle of keeping the less sonorous member of the cluster.

There are two approaches within Optimality Theory for explaining the reduction of /s/ clusters that have been widely discussed in the literature (Pater and Barlow's 'factorial typology', 2003, and Goad and Rose' 'headedness', 2004). Briefly stated, in this framework constraints evaluate possible outputs and the interaction of two forces – faithfulness constraints and markedness constraints – determines which of the several potential outputs will be chosen. The common occurrence in children's reductions is sonority-based in that the least sonorous segment of the target is retained (i.e., reducing '/s/+stop' to a 'stop', and '/s/+ sonorant C to /s/ as with speak [spik] → [pik], and sleep [slip] → [sip]). An interesting exception to the sonority pattern is observed, however, when other processes play a role, as observed by Pater and Barlow (2003). For instance, the occurrence of stopping in the sound system of a child who also exhibits #sC cluster reduction may result in a number of cluster reduction patterns, depending on how extensively stopping pattern applies. That is, it is common for stopping to occur in some but not all contexts.

For example, a child might apply stopping in clusters, but not singleton onsets (e.g., swim → [twɪm] but sun → [sʌn]). Pater and Barlow (2003) in their 'factorial typology' make interesting predictions regarding the variation that may occur with the interaction of these two patterns. They argue that children's grammars can differ in terms of how the constraint related to stopping and those related to sonority-based cluster reduction are ranked, yielding a typology of possible #sC reduction grammars. Accordingly, they state that if a segment of given sonority is retained instead of the fricative, i.e. /s/, then all segments of lesser sonority will be chosen in retention instead of the fricative. Thus, we have, the following predictions on the basis of retained C2 in the reduction: lower sonority segment is retained (A, in table 1a below), lower sonority segment is retained in the two targets where the sonority difference between C1 and C2 is greater (B, in table 1a below); lower sonority segment is retained only in the target in which the sonority difference between C1 and C2 is the greatest (C, in table 1a below). Finally, if an sC cluster retains the more sonorous C2 segment rather than [s], then all segments of lesser sonority will also be chosen instead of the fricative for other #sC clusters (D, in table 1a below). Thus, if /sw/ reduces to [w], then /sl/ will reduce to /l/, and /sN/ to nasal. Accordingly, patterns depicted E – N are predicted not to occur (table 1b).

Table 1a and b about here

The second approach called "headedness", advanced by Goad and Rose (2004), predicts the preservation of the cluster heads in the reduction. In this approach, the different outputs children exhibit should be explained via the child's knowledge of the syllabification of the clusters. In other words, the elaboration of the input, rather than the typical re-ranking of the processes, is responsible for children's selection of the heads in the input. Accordingly, children first select the head of a cluster via sonority ("sonority stage"). This purely phonetic sonority pattern treats the lower sonority item as the head and thus it is retained in the reduction (e.g. stop [stɑp] → [tɑp], lower sonority /t/ is the head and thus retained; sleep [slip] → [sip], lower sonority /s/ is the head and thus retained). Later, when the child discovers that sC is an adjunct cluster with /s/ outside the constituent ("head stage"), what is preserved in the reduction is the head (i.e., C2) and not /s/ (e.g. in sleep [slip] → [lip], /s/ is an adjunct, and /l/ is the head, so it is retained; in stop [stɑp] → [tɑp], /s/ is an adjunct, and /t/ is the head, so it is retained). Jongstra (2003) presents a slightly different version of this approach by drawing attention to the sonority distance between the two members of the cluster in the head assignment. She argues that when the cluster members have closer sonority values as in "fricative+nasal" or "fricative+lateral" clusters (e.g. snake and sleep), it becomes more difficult for the child to identify which consonant is the head and which the non-head. Consequently, such clusters may show more between-child variability (e.g. snake [snek] may be [sek] in one child and [nek] in another) than clusters whose members have greater differences in sonority (plate [plet] is consistently reduced to [pet] not to *[let]).

Cross-linguistic studies on the reductions of initial /s/ clusters reveal rather well-defined patterns, as shown in table 2.[3]

Table 2 about here

As it is clear from the display, the consonants retained in the reductions and their degrees of preferences are not equal. For example, while in all six languages C2 is the preferred retained member for /sT/ targets, it is absolute (100%) in Croatian (Mildner & Tomic, 2010, 30 children between the ages 2;1 and 3;9, mean age 3;1) and it is lower in Hebrew (85%) (Ben-David, 2006, 40 children between the ages 1;10 and 3;0, mean age 2;6), and in Polish (84%) (Yavaş & Marecka, 2014, 25 children between the ages 2;9 and 4;3, mean age 3;5). C2 is also preferred in /sN/ targets. Here, Norwegian shows the highest preference (97%). The reductions for /sl/ reveal the preference of retaining C1 (i.e., /s/). This is absolute in Croatian (Mildner & Tomic, 2010) and Norwegian (Kristoffersen & Simonsen, 2006, 27 children between the ages1;9 and 3;0, mean age 2;6), quite high in English,(85%) (Yavaş & Core, 2006, 40 children between the ages 2;5 and 4;2, mean age 3;1), and lower in Hebrew (68%) and Dutch (63%), (Gerrits & Zumach, 2006, 45 children between the ages 2;2 and 3;6, mean age 3;0). This target is not included in Polish, because it is a rare cluster in the language, occurring mainly in borrowings. The remaining targets /sw/ /sʁ/ and /sʋ/ also shows the preference for C1 as the retained member. Here again, the percentages vary. The preference is absolute in Croatian, very high in Hebrew (92%), but lower in the remaining languages.

In summary, we can say that, with varying degrees, C2 is the preferred retained member for /sT/ and /sN/ targets, whereas C1 is the preferred retained member for /s/+ approximant/ targets. As such, the results do not lend themselves to any sonority-based explanations. The alliance between the falling (negative) sonority /sT/ clusters and the rising (positive) sonority /sN/ clusters suggests that the 'continuancy' of C2 is the determining factor; C2 prevails in "/s/+[-continuant]" targets. If on the other hand, both members are [+continuant], i.e., /s/ + approximant', where C1 is retained, sonority may be the ancillary factor. Thus, the generalisations for reductions can be formulated in the following manner:

	C1	C2		
If:	/s/	T / N	Then: →	T / N
	[+cont]	[-cont.]		[-cont]
If:	/s/	approximant	Then: →	mostly /s/
	[+cont.]	[+cont.]		lower sonority

When these results are interpreted through the lenses of the two approaches detailed earlier, we see the validation of the predictions of ‘factorial typology’ (Pater and Barlow, 2003), but difficulties for the ‘headedness’ approach (Goad and Rose, 2004). ‘/s/+nasal’ targets clearly favour the retention of C2 (nasal): this finding does not fit into the “sonority pattern” (stage I in development), where the least sonorous consonant in the cluster should be retained. The “head” pattern (stage II in development), in which /s/ is adjunct and the other consonant (i.e., C2) is the head, predicts that the head will be retained. While this can account for the tendencies exhibited for ‘/s/+ stop’ and ‘/s/+ nasal’, it runs counter to the data for others.

The Study

To further validate the results obtained in cross-linguistic studies cited above, the database needs to be expanded. The present study is an attempt to this end. Patterns of reduction in German ʃC cluster acquisition data can add to our understanding of’ ’coronal strident + C’ behaviour.

The research questions in this study we pose are:

a) Do German reduction data lend themselves better to the predictions of ‘factorial typology’ or to those of the ‘headedness’ approach?
b) Do German ʃC cluster reductions show the expected patterns based on results reported for sC clusters of several languages in the literature?
c) If differences are found between German results and other languages, what are the possible explanations?
d) Is there differential behavior with respect to different ʃC targets in terms of suppressing the reduction and moving to the stage of cluster formation?

Participants

The present data of 145 children aged 2;00 - 2;11 were extracted from different cross-sectional studies, (those studies involved a total of 717 children aged 2;00-5;11 to investigate the phonological acquisition in German-speaking children). We chose this age group because we know from earlier studies that children from age 2;0 onward produce clusters, and we were interested in the early acquisition process. Data were collected between 1999 and 2012 in different urban and rural areas across Germany which included a range of different dialectal variations and children with different levels of socioeconomic status. Children were assessed across Germany but the vast majority came from regions where a /ʁ/ is to be expected. There were no children from the small regions using /r/. Some children produced a phonetic variation towards [x]. Children did not come from strong dialectal regions, thus there were no expected variations on /v/ (see also Schaefer & Fox-Boyer, 2017).

To ensure that all children met the inclusion criteria, parents and caregivers were asked to complete a questionnaire about their children's language and developmental histories. Selection criteria were included as follows: monolingual German-speaking children, no history of speech and language difficulties, no significant hearing loss, no other physical / cognitive impairments.

Material

Two versions of the Psycholinguistische Analyse Kindlicher Aussprachestörungen (PLAKSS-II, Fox-Boyer, 2014; PLAKSS, Fox, 2005), a well-established picture naming test to assess phonetic and phonological skills in German-speaking children, were administered. The PLAKSS's qualitative and quantitative analysis provides an overview of the child's phonetic and phonemic inventory, including phonological processes. All seven German two-member word-initial /ʃ/-clusters are included and tested with one item each, for /ʃt/ and /ʃl/, two items (see appendix A). Most of the items were bisyllabic. Except for two items the cluster structure always occurred in word initial position and the first syllable was also the stressed syllable of the word (exceptions: /ʃɔɐnʃtaɪn/, <chimney> (the cluster is in the second, unstressed syllable); /gəˈʃpɛnst/ <ghost> (the cluster is in the second, i.e., stressed syllable). We compared the cluster productions in these words with other test items including the clusters /ʃp/ or /ʃt/, checking if word position/stress patterns affected the results qualitatively or quantitatively. This was not the case.

As a final note in this section, we also give the following information regarding the acquisition of singletons that make up the clusters. Data on the acquisition on singletons which are part of the target clusters in German ʃC, /m, n, v, p, t, ʁ, l/, indicate that all, except /ʁ/ (2;11), are acquired by 75% of the 20 children assessed before the age of 2;0 (Fox & Dodd, 1999). Phonemically, no phonological processes can be found for any of these targets, apart from /ʁ/, before 2;5 (Fox-Boyer, 2016). /ʁ/ was replaced by [h] up to the age of 2;5 by a small number of 43 children assessed. The singleton /ʃ/ is acquired latest by the age 4;11 and can be backed to /ç/ until the age 2;11 and fronted by 10-20% of the children to [s] until the age 4;11 (Fox-Boyer, 2016).

Procedure

Children were presented with pictures one at a time and were asked to name them. When children were not able to independently name the picture, they were offered three cues in the following order: a cloze sentence (e.g. the farmer drives a…), alternative choices (e.g. is this a snake or a bear?), or the child was asked to repeat the word.

Speech assessments were carried out by qualified speech and language therapists (SLTs) or trained final year SLT students in a quiet room within the nursery (76%) or at the children's home (24%). Parents or caregivers were allowed to attend the test session which lasted approximately 5 to 25 minutes depending on the attention and motivation level of the child and the test version administered. Broad online transcription was used by the testers during the assessment. All transcriptions were checked against audio-recordings (devices used: Sony Professional Micro Stereo recorder + Olympus W650S, the microphone was placed on the table around 20-30 cm away from the child's mouth) following the test sessions. Experienced SLTs (not the testers) scored 10% of all recordings to determine inter-rater reliability. The inter-rater reliability for all data including sibilant clusters was 98.3%.

Data analysis

A qualitative analysis of the reduction patterns was carried out. For each cluster the number and percentage of reductions to either the first (C1) or the second element (C2) were calculated. When additional substitution processes occurred, which unambiguously were connected to C1 or C2 i.e., fronting of /ʃ/ to /s/ (e.g. Spinne (spider) /ʃpɪnə/ > [sɪnə]) or backing of /t/ to /k/ (Stuhl (chair) / ʃtul/ [kul]) these were also included in the calculation. Some of the children produced the replacement sound /s/ interdentally. This only occurred in children who consistently realised /s/ or /z/ interdentally. Further, some children realised /ʃ/ as lateral /ɬ/, both on single consonant and consonant cluster level. Since there is no phonemic contrast in German between /ʃ/ and /ɬ/ or /s, z/ and / θ, ð/, the interchangeable production does not result in different meanings of the words. In addition, a high percentage of children show those phonetic variations up to the age of six (see Fox-Boyer, 2016). Hence, those phonetic mispronunciations were not considered for the current analyses.

Further, phonetic variations of /r/ productions (i.e., [ʁ̥] for [ʁ]), interdental realisations of /s/ and voicing changes ((de)voicing, e.g. Brot (bread) [bʁot] > [pʁot]) were ignored. (De)-voicing of consonant clusters occurs as dialectal variation in different regions across Germany. Additionally, as Macken and Barton (1980) and Ota & Green (2013) argue, phonetic boundaries for voicing differ in children in comparison to adult-like productions (see Ota & Green, 2013, p. 548).

Results

The reduction patterns revealed by the German-speaking children, aged 2;0 – 2;11, are given in table 3. For each cluster, the number and percentages are given. As stated earlier, the substitutions of [s] and [ç] for /ʃ/ as C1 are included here. When C2 is retained, no substitutions were observable other than voicing errors (/v/ → [f]). In some instances, the reductions of clusters to one segment could not be unambiguously identified as either C1 or C2; these are given under the 'other' column in the table.

Table 3 about here

Overall, reductions were found in approximately 30% of the /ʃC/ targets; they were higher in /ʃT/ and /sm/ targets than others. As can be seen, for targets with [-continuant] C2 ('/ʃ/+stop' and '/ʃ/+nasal'), the preference for the retained C2 consonant is strong (the strength varies from 85/82% for /ʃn/ and /ʃm/, respectively, to 90% for /ʃp/). As for the '/ʃ/ + approximant/ targets (/ʃl/ and /ʃʁ/), we can see that the preference is slightly in favor of C1 for /ʃʁ/ (43% vs. 30%)[4], whereas there does not seem to be a favorite consonant retained for /ʃl/ (37% for C1 vs. 35% for C2). An additional target that patterns the same way as the /ʃT/ clusters favoring the retention of C2, is /ʃv/ (76% of C2 vs. 12% of C1)). This particular target does not belong to the two groups discussed above and will be discussed in detail below.

However, if we only consider the reductions where the retained consonant is unambiguously identified, then the tendencies become more pronounced, as shown below.

<u>C1 retained</u> <u>C2 retained</u>

/ʃp/	1/46 (2%)	45/46 **(98%)**
/ʃt/	10/39 (25%)	29/39 **(75%)**
/ʃv/	4/30 (13%)	26/30 **(87%)**
/ʃm/	2/41 (5%)	39/41 **(95%)**
/ʃn/	4/27 (15%)	23/27 **(85%)**
/ʃʁ/	13/22 **(59%)**	9/22 (41%)
/ʃl/	13/25 (52%)	12/25 (48%)

Discussion

When we evaluate the results from German reduction data through the lenses of the two approaches, 'factorial typology' and 'headedness', the former seems to more adequately account for the data. The relationship of reductions between /ʃl/ and /ʃN/, two rising sonority '/ʃ/ + sonorant' clusters elucidates the situation quite well. According to the 'factorial typology', if a child reduced /ʃl/ to [l], then the reduction of /ʃN/ is expected to be the /N/, the prediction validated by our results. On the other hand, the 'headedness' approach expects the child to be either in stage 1 (sonority stage) reducing 'sibilant + sonorant C' to the lower sonority C1 (i.e., /ʃl/ → [ʃ], and /ʃN/ → [ʃ]), or in stage 2 (head stage) wherein the sibilant (adjunct) would be deleted and the C2 retained (sonorant C). However, the fact that the majority of children reduce /ʃN/ to [N], but only half reduce /ʃl/ to [ʃ] (or [l]) does not conform with either stage. Jongstra's (2003, 115-119) suggestion which states that 'if the cluster members are close to one another in sonority indices, then the preference will not be clear' is not confirmed either. Despite the fact that /ʃN/ (ʃn/ and /ʃm/) are also close in sonority, a clear C2 preference for retention is observable. Also, our participants' behavior regarding the reduction of /ʃv/ and /ʃl/ is worth mentioning. According to Jongstra, /ʃl/ should be a better cluster (sonority rises from C1 to C2 more sharply) than /ʃv/ (flat-sonority, both fricatives). The expected result from this is that more variable productions should be observed in the reductions of the latter target. However, the results show a more decisive pattern for /ʃv/ than for /ʃl/.

Regarding the research questions (b) and (c), that is the comparison of the German reduction data with those of other languages, we can say that the overall results we obtained with several targets discussed above are not surprising. For targets with [-continuant] C2 (/ʃ/+stop/ and /ʃ/+nasal), retention of C2 is the strong preference, and this matches well with the reduction patterns observed cross-linguistically. When turning the attention to /ʃ/ + approximant/ targets (/ʃʁ/ and /ʃl/), we see that German, by favoring the retention of C1, follows the cross-linguistic tendency with respect to the former target, while showing an indecisive result for /ʃl/. We do not have a satisfactory explanation for this last target. However, we can mention the fact that its [+continuant] and 'approximant' status has not been uncontroversial. Wiese (1996) treats /l/ as [-continuant]. Also suggested by others that German /l/ is in much stronger in contact than glides and fricatives; the air flows along one side of the tongue in the oral cavity but is blocked on the other. Thus, its status is in between [+] and [-] continuant.[4]

We seem, however, to have a totally unexpected situation with /ʃv/ targets, a flat / level-sonority cluster with two fricatives [5] [6]. As shown above, children have a strong preference for C2 retention for this target, 26 out of total of 34 cases (76%), and 87% when 'other' are excluded. As such, reduction patterns for this target follows the patterns observed for /sT/ and /sN/, which have [-continuant] C2s. To attempt an explanation through the continuancy of C2 runs into difficulty because it contradicts the above formula in that C2 retention is predicted for [-continuant] C2s. Since /v/ is [+continuant], more preference should be on C1 retention, but this clearly is not the case.

What, then, can be an explanation for the unexpected behavior of this flat/level-sonority target? One question comes to mind is the quality of German /v/. Perhaps its continuancy / degree of narrowing should be questioned: is /v/ less continuant than /ʃ/? (with more obstruction, friction)? Since /v/ is a voiced fricative, the oral pressure should be low for the sake of continued voicing. On the other hand, for the sake of frication, the oral pressure should be high enough to cause high air velocity through the consonantal constriction. In other words, to the extent that the segment retains voicing, it may be less of a fricative. This is well captured by Ohala (1983; 201) who states that "if it is a good fricative, it runs the risk of being devoiced". Wiese (1996) suggests that German [v] is often realized as voiceless, especially if it follows a voiceless obstruent. In fact, as reported by Schaefer & Fox-Boyer, 2017, out of 26 C2 retentions of /ʃv/ reductions in the data 12 are realized as [f] (as opposed to 15 [v]). Regardless of this fact, however, it is difficult to argue that the C2 in this target is less continuant (greater obstruction than /ʃ/) or is less sonorous than /ʃ/.

One may also entertain the idea that the reason for the retention of [v] may have to do it with the fact that it is an early acquired sound and children move on the clusters with what they have strongly in place as singletons. However, this does not seem to be a viable explanation because [v] and [s] (the fronted substitute for /ʃ/) are acquired the same time in German. Also, we find [f] as the retained C2 (instead of [v]) in several children, which is normally acquired later than [s] (C1).

Bjorndahl (2015) states that /v/ can challenge the phonetics and phonology of segment classification in languages. Through an examination of the acoustic measures 'spectral centroid' and 'skewness' to quantify the degree of frication, Bjorndahl concludes that while Russian /v/ is more like a [v], Serbian /v/ is more like [ʋ]. Hamann & Sennema, (2005a, b), examining the acoustic measures 'duration' (ms), 'harmonicity median'(db), and 'center of gravity' (kHz), conclude that German /v/ is more like Dutch /ʋ/. If this is the case, then the situation is similar to what we have in Norwegian and Croatian /sʋ/, and the reduction patterns in German should mimic what we find cross linguistically. That is, "reductions of voiceless strident coronal + frictionless continuant / glide clusters generally result in the retention of C1", which is shown through data from normally developing children in English, Norwegian, Croatian, and Polish, in table 3.

As we see, however, German /ʃv/ targets are predominantly reduced to C2. In view of the lack of any coherent explanations, we are left with the following two descriptive statements for the reduction patterns in German, which is not part of either 'factorial typology' or 'headedness:

1) In all cases in which predominantly C2 is retained (/ʃp, ʃt, ʃv, ʃm, ʃn/), the retained C is anterior to /ʃ/ (the most anterior constriction wins out, regardless of its continuance), and this suggests a place constraint.
2) The mostly C1 retaining /ʃ+liquid/ clusters involve a sort of articulation that involves the tongue body to some degree (whereas C2 retaining reductions all involve labial or exclusively coronal articulations).

With regard to our last research question, (d), the trajectory 'from no cluster to a target-like cluster', can, and indeed does, go differently with different children. Some establish the ambient-like clusters both phonologically and phonetically and reaching there more or less at the same time for all targets. Some other children, on the other hand, may go through a stage whereby cluster productions are phonologically formed, but phonetically inaccurate. In other words, a two-member cluster may be produced without being target-like phonetically. Obviously, this is still a significant development as it indicates a phonological change in the system and needs our attention. If we exclude children who have completed the development of all targets phonologically and phonetically and those who haven't gone beyond the reduction stage for any target, i.e. no evidence of a cluster phonologically, we see some children who treat target clusters differentially. In other words, while some targets are still in the reduction stage (no cluster phonologically), other targets are realized as clusters phonologically without having accurate productions phonetically. Examining the data from this perspective and grouping the targets as /ʃ/ + stop/, /ʃ/+nasal/, /ʃv/, /ʃʁ/, and /ʃl/, we do not find any one target realised phonologically correctly while others are still being reduced. On the other hand, the opposite tendency is found in some children; one and the same target, /ʃv/, is kept in the reduction stage, while others reaching the phonologically correct (but phonetically erroneous) status. This is the pattern for five children who show differential treatment of the targets by singling out and leaving /ʃv/ behind while they form the other clusters phonologically. In addition, one child had no production for /ʃv/ target while having clusters established phonologically for other targets.

Needless to say, such a situation warrants an examination of some potentially explanatory avenues. One hypothesis centers on the frequencies of German initial ʃC clusters. We can entertain the possibility that /ʃv/ stays behind the other targets in the establishment of the phonological cluster due to its low frequency. Table 4 gives the type and token frequencies of these clusters based on CELEX (Aichert, Marquardt & Ziegler, 2005).

Table 4 about here

It should be clear from the above table that the frequencies (type or token) are not in any way relatable to the so-called well or ill-formedness of the cluster with respect to the SSP. As we see, the ill-formed (negative sonority) /ʃt/ and /ʃp/ are the two most frequent clusters, and the well-formed /ʃn, ʃm, ʃʁ/ are below the flat-sonority /ʃv/ and at the bottom of the frequency list. Thus, /ʃv/ has no special status with respect to the frequency (type or token); it is neither the least frequent, nor is it the most ill-formed with respect to the SSP.

Additionally, we can examine the situation in relation to the OCP [continuant] perspective. Some studies in interlanguage phonologies show greater production accuracy in negative sonority (i.e., /s+stop/), and short-rise sonority (i.e., /s+nasal/) targets than greater sonority-rising clusters (i.e, /s+approximant/) in terms of OCP for continuance (Abrahamsson, 1999; Enochson, 2014). Simply stated, OCP is a principle disfavoring near identical segments. Thus, clusters that violate OCP [continuant] (i.e., /ʃ/+continuant) are more marked than those that obey OCP [continuant] (/ʃ/ + stop / nasal). Looked at from this perspective, /ʃv/ is not unique; it is not abiding by that sequencing, but in no way different from /ʃl/ and /ʃʁ/ in that respect. Interestingly, in addition to the five children cited above, two other children show target-specific (differential) patterns of development by staying behind with reductions in /ʃv/ and /ʃʁ/, while advancing to the level of phonological cluster (but phonetically inaccurate) in other /ʃC/ targets. To add to the similar behavior of these two targets (/ʃʁ/ and /ʃv/), six children are noted to have no productions for these, while producing phonological clusters for the remaining targets. It seems that these cases are also explainable invoking OCP [continuant], if we adhere to the position taken by Krech et. al. 2009, Kohler 1999, Ladefoged & Maddieson 1996, and Mangold 2005 and treat /ʁ/ as a velar / uvular fricative.

Another element to consider regarding the uniqueness of /ʃv/ is to examine the number of word types in child speech. Table 5 displays that from the German dictionary Duden.

Table 5 about here

Here again, the order seems to be similar with the one above and does not provide any insight into the uniqueness of /ʃv/. Neither the SSP, nor the OCP [continuant] can provide any explanation. While these possibilities are inadequate to explain the special status of /ʃv/, the combination of the two – the SSP and OCP [continuant] may account for it. This target is the only one of the German

#/ʃC/ clusters that does not abide by either the SSP (flat sonority) or the OCP [continuant]. In other words, while the two factors considered are not sufficient individually, together they seem to account for the unique status of /ʃv/.

Conclusions

In this paper, we examined factors affecting the acquisition of ʃC clusters by German-speaking children with special emphasis on cluster reduction patterns. Data from 145 children ages 2;0 – 2;11 revealed some well-defined tendencies with respect to the consonant retained / deleted. In targets with [-continuant] C2s (i.e., /ʃp, ʃt, ʃm, ʃn/), the retained consonant in the reduction was decidedly, and expectedly, the C2. In targets with an approximant ([+continuant]) C2 (/ʃl, ʃʁ/), the preference for the retained consonant was slightly in favour of the C1 for /ʃʁ/, an outcome which was not very different from many other languages. The indecisive nature of /ʃl/, on the other hand, may be due to its dubious character for [continuant]. This issue calls for a detailed investigation in future studies for a better understanding. However, there was one target, /ʃv/, whose reduction revealed a totally unexpected outcome as the retention favoured C2 ([v]). This was unexpected because, as mentioned above, when C2 in the cluster is [+continuant], the retained consonant in reduction was more commonly the C1. The unexpected nature of this reduction was further supported by the phonetic quality of German [v] and its similarities to [ʋ], a sound when clustered with a voiceless sibilant fricative as C2 (e.g./sʋ/), is not typically reduced to C2 [ʋ]; as shown earlier in Norwegian and Croatian, /sʋ/ is more commonly reduced to C1 ([s]). For lack of a better explanation, the pattern observed in the German data, which puts /ʃv/ together with /ʃT/ and /ʃN/, was attributed to a place constraint. Examined through the principles of the two approaches 'factorial typology' and 'headedness' the former seems to account for the data better. Yet, the elusive status of /ʃv/, which was explainable through place of articulation, is not successfully accounted for in either approach.

When children progressed from the reduction phase to forming clusters in production, different patterns were observed with different children. Some children created this structural change indiscriminately, in that all ʃC targets were produced as clusters in the ambient language (phonologically and phonetically accurate). In some others, some targets were realised like the ambient language (accurate both phonologically and phonetically), while other targets were phonologically clusters without having accurate phonetic realisation (phonologically correct but phonetically incorrect). Yet, in some other children, we found certain targets reached the phonologically correct status while other targets were still in the reduction phase. In the examination of the last group, it was noticed that no single target was advanced to the phonological cluster level while leaving all other targets in the reduction stage. However, one target, /ʃv/, was found to have stayed behind in the reduction phase (or with no production at all) while all others advanced to the structurally 'cluster' stage (without necessarily having accurate phonetic rendition). In search of an explanation for the unique behaviour of this particular target, we looked at type and token frequencies in the German lexicon as well as word types for child appropriate vocabulary. Neither factor alone seemed satisfactory in accounting for the specific behaviour of /ʃv/. We suggest that, the uniqueness of this target may be due to its non-abidence to the SSP and the OCP [continuant].

Finally, a few words on clinical implications are in order. Patterns found in typical development are of great value in clinical setting, because findings can help clinicians in terms of appropriate selection of treatment targets for the children with phonological delay or disorders. Identification of predictive and implicational relationships between the targets may be utilized during remediation, because teaching one type of cluster may impact production of others. We can, for example, take leads from degrees of phonologically correct clusters. If one holds the widely adhered view (Dinnsen and Elbert, 1884; Tyler and Figurski, 1994; Gierut, 1998, 1999) that targeting a structure of a higher-level complexity (i.e. more marked) should cause structures from lower levels to emerge, then the choice would be more the marked /ʃv/, the target that does not abide by the SSP and the OCP [continuant].

Since our study is based on cross-sectional data, it was not possible to state the gradient and implicational changes of cluster development within each child. That is, we would like to know if sonority differences between C1 and C2 and /or OCP [continuant] resulted in any implicational patterns in the development of a subgroup of /ʃC/ clusters. More specifically, does achieving the cluster stage (i.e. suppressing the reduction) with /ʃT/ imply suppressing /ʃN/? or vice versa? Does homorganicity in /ʃT/ imply anything for homorganicity in /ʃN/ or /ʃl/? Obviously, the answers to these and similar questions, which will enhance our understanding of development and can make significant contribution for clinical intervention, can only come from longitudinal investigations. Studies of this nature, together with delving into the ambiguous nature of the German /l/, should be the next avenues to explore.

NOTES

1- There are, however, instances whereby the target cluster is modified by epenthesis (e.g. 'blood' [blʌd]→[bəlʌd]), and coalescence (e.g. 'swim' [swɪm] → [fɪm] or 'smoke' [smok] → [fok], whereby the labiality of /w/ and /m/ the frication of /s/ are combined in [f]).

2- Besides the 'adjunct' (appendix) status discussed above, there are several other proposals in the literature regarding the formal representation of sC clusters. We will not go into the details of these positions here (for a comprehensive account of these different positions, see Goad (2011).

3- The subjects in the studies cited below were chosen from the participants who had the mastery of single onset /s/ and the C2 of the clusters in question and showed some signs of acquisition of #sC clusters without having completed the acquisition of all #sC clusters. This criterion excluded children who produced all #sC clusters correctly and those who produced all targets incorrectly. The studies all involved a picture-naming task.

4- We are indebted to one of the anonymous reviewers for this point.

5- Wiese (1996) does not treat German [ʃv] as a flat sonority cluster because he argues that [v] is /ʊ/ underlyingly, and that sonority is relevant for more abstract representation, not the surface phonetic form. However, as stated by van de Vijver & Baer-Henney (2012), this is not tenable, as there are no alternations between [v] and [ʊ].

6- Regarding their sonority levels, different sonority scales are suggested in the literature. In Hogg and McCully's (1987) 10-point scale, voiceless fricatives are ranked lower in sonority than voiced fricatives. Selkirk (1984), on the other hand, draws a finer distinction among fricatives and considers /s/ higher in sonority than /v, z, δ/, a view which is not shared by many.

Appendix A: Initial /s, ʃ/+C clusters in English and German

	English	German
/s/ ʃ/+ stop	sp st sk	ʃt ʃp
/s/ ʃ/+ nasal	sn sm	ʃn ʃm
/s/ ʃ/+ /ɹ/ʁ/	ʃɹ	ʃʁ
/s/ ʃ/+ /l/	sl	ʃl
/s/ ʃ/+/w/ or /v/	sw	ʃv

Note. * English and German, Wiese (1996)

Appendix B: Item List of ʃC Clusters of PLAKSS-I and II

Item	Translation	Transcription
Stuhl	Chair	ʃtul
Spinne	Spider	ʃpɪnə
Schnecke	Snail	ʃnɛkə
Gespenst	Ghost	gəʃpɛnst
Schrank	Wardrobe	ʃʁaŋk
Schlange	Snake	ʃlaŋə
Schornstein	Chimney	ʃɔɐnʃtaɪn
Schlüssel	Key	ʃlʏsəl
Schmetterling	Butterfly	ʃmɛtalɪŋ
Schwein	Pig	ʃvaɪn

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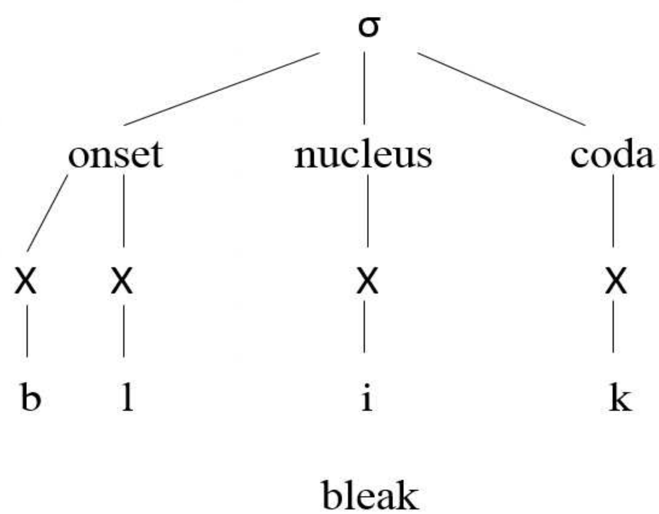
Figure 1. True Clusters and Adjunct Clusters

‘true cluster’ (complex onset)

Canonical (obst. + liquid)



‘adjunct cluster’

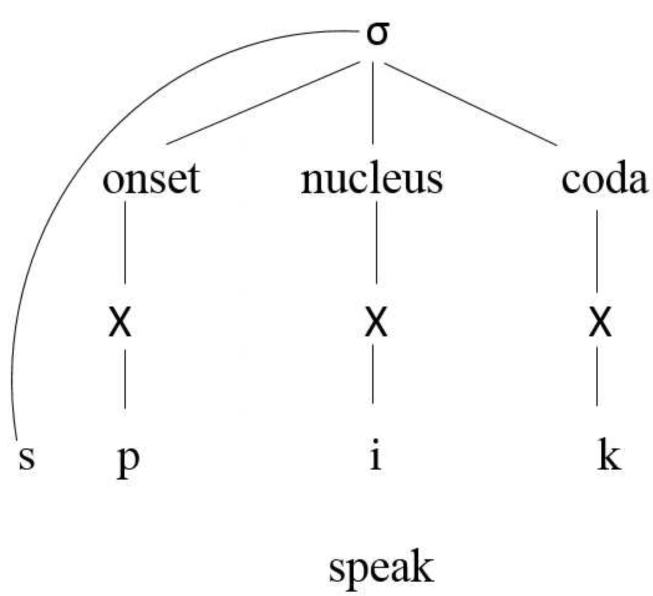
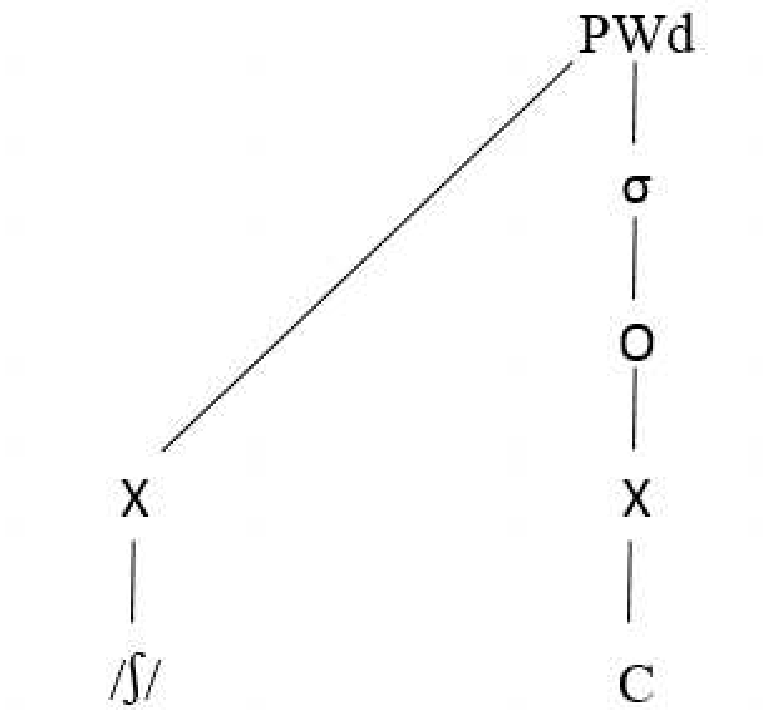


Figure 2. German ʃC



PWd = prosodic word; σ = syllable;
O = onset; X = skeletal position;
C = consonant

Table 1.a) Factorial typology sC reduction predictions (after Pater & Barlow, 2003)

	sT	sN	sl	sw
A	T	s	s	s
B	T	N	s	s
C	T	N	l	s
D	T	N	l	w

1.b) #sC reduction patterns predicted not to occur

E	s	N	l	w
F	T	s	l	w
G	T	N	s	w
H	s	s	l	w
I	T	s	s	w
J	s	N	s	w
K	s	N	l	s
L	s	s	s	w
M	s	s	l	s
N	s	N	s	s

Table 2. Summary of reduction patterns across different languages. Percentage points are given in the order of the preferred retained consonant over the other (e.g. English /sT/: C2 retained 83%, C1 retained 17%) (after Yavaş, 2013)

	Eng.	Dutch**	Norw.****	Heb.***	Croat. ****	Polish*
/sT/	C2(83/17)	C2(82/18)	C2(88/12)	C2(85/15)	C2(100/0)	C2(84/16)
/sN/	C2(84/16)	C2(71/29)	C2(97/3)	C2(70/30)	C2(85/15)	C2(63/37)
/sl/	C1(85/15)	C1(63/37)	C1(100/0)	C1(68/32)	C1(100/0)	--- ---
/sw/	C1(73/27)	--- ---	C1(67/33)	C1(92/8)	C1(100/0)	C1(60/40)

*no /sl/; **no /sw/; ***no /sw/, /sʁ/ was looked at instead; ****no /sw/, /sʋ/ was looked at instead.

Table 3. Reduction patterns in German ʃC clusters (consonant retained)

	C1 (ʃ/s/ç)		C2		Other		Total
	N	%	N	%	N	%	
ʃp	1	2	45	**90**	4	8	50
ʃt	10	23	29	**66**	5	11	44
ʃv	4	12	26	**76**	4	12	34
ʃm	2	4	39	**82**	7	14	48
ʃn	4	15	23	**85**	-	**-**	27
ʃʁ	13	**43**	9	30	8	26	30
ʃl	13	37	12	35	10	28	35

	Phoneme Corr CC		Phone Corr CC		Reductions		C1 ret		C2 ret		other red	
Target	N	%	N	%	N	%	N	%	N	%	N	%
ʃp	89	64	31	22	50	36	1	1	45	33	4	3
ʃt	90	67	31	23	44	33	10	7	29	21	5	4
ʃv	72	64	32	29	34	30	4	4	26	23	4	4
ʃm	85	63	35	26	48	35	2	1	39	29	7	5
ʃn	83	73	33	29	27	24	4	4	23	20	0	0
ʃʁ	66	64	31	30	30	29	13	13	9	9	8	8
ʃl	105	74	31	22	35	25	13	9	12	9	10	7

Table 4. Type and token frequencies in German ʃC (Aichert, Marquardt & Ziegler, 2005)

	token frequency	type frequency
ʃp	3.631	141
ʃt	17.498	331
ʃv	2.279	164
ʃm	343	93
ʃn	744	74
ʃl	3.674	176
ʃʁ	1.952	93

Table 5. Number of word types in German child speech (From German Dictionary Duden) (Mangold, 2005)

cluster	number of word types
ʃt	> 50
ʃl	23
ʃp	21
ʃv	18
ʃʁ	12
ʃn	9
ʃm	8