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The effect of phonotactic constraints in German-speaking children with delayed phonological acquisition: Evidence from production of word-initial consonant clusters

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Abstract

In this study the effect of phonotactic constraints concerning word-initial consonant clusters in children with delayed phonological acquisition was explored. Twelve German-speaking children took part (mean age 5;1). The spontaneous speech of all children was characterized by the regular appearance of the error patterns fronting, e.g., *Kuh* "cow" /ku:/ → [tu:], or stopping, e.g., *Schaf* "sheep" /ʃa:f/ → [ta:f], which were inappropriate for their chronological age. The children were asked to produce words (picture naming task, word repetition task) with initial consonant clusters, in which the application of the error patterns would violate phonotactic sequence constraints. For instance, if fronting would apply in /kl-/, e.g., *Kleid* "dress", it would be realized as the phontactically illegal consonant cluster /tl-/. The results indicate that phonotactic constraints affect word production in children with delayed phonological developments. Surprisingly, we found that children with fronting produced the critical consonants correctly significantly more often in word-initial consonant clusters than in words in which they appeared as singleton onsets. In addition, the results provide evidence for a similar developmental trajectory of acquisition in children with typical development and in children with delayed phonological acquisition.

Keywords: *Children with delayed phonological acquisition, phonotactic constraints, word-initial consonant clusters, fronting, stopping.*

Introduction

The most common communication disorder in childhood is an impairment of phonological/phonetic abilities. Between 3% and 10% of children are affected by this type of language disorder (Gierut, 1998). In this area, previous research has mainly focussed on phonological development of phonemes, segmental features, syllable structures or prosodic features (e.g., Fikkert, Penner, & Wymann, 1998; Grunwell, 1987; Hacker, 1999; Ingram, 1976; Leonard, 1985). There are also few studies that focus on consonant cluster acquisition by children with delayed phonological acquisition mainly analysing cluster reductions, cluster simplifications and the order of acquisition of cluster categories (e.g., Chin & Dinnsen, 1992; McLeod, van Doorn, & Reed, 1997). On the other hand, the effect of phonotactic constraints on the acquisition of consonant clusters in children with delayed phonological acquisition has not been investigated in much detail; therefore the goal of this study is to observe whether phonotactic constraints referring to word-initial two-element consonant clusters affect the word production of German-speaking children with delayed phonological acquisition.

"Phonotactic probability", as one part of phonotactics, refers to positional segment frequency, i.e., the likelihood of occurrence of a given sound in a given word position, and differentiates sound sequences that are common from those that are rare. For example, /s/ has common probability and /ʃ/ has rare probability of occurrence in word-final positions in English (see e.g., Storkel, 2001; 2004; Storkel & Rogers, 2000; Zamuner, Gerken, & Hammond, 2004, for fuller discussion). In this regard, the results of Storkel and Rogers (2000) and Storkel (2001) indicate that English pre-school- and school-age children are influenced by the likelihood of sound occurrence when learning new words.

"Phonotactic constraints", as applied to acquisition, are rules that describe for a given child the set of sounds that occur in production (i.e., inventory constraints) and describe context-conditioned limitations in sound occurrence (i.e., positional constraints). For instance, in German the sound /θ/ is not part of the inventory, voiced obstruents and the

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laryngeal fricative /h/ do never occur in syllable-final positions (e.g., Wiese, 1996). Moreover, restrictions on the co-occurrence of sounds (i.e., sequence constraints) are described by phonotactic constraints (e.g., Dinnsen, 1984; Elbert & Gierut, 1986). Within these sequence constraints, sonority plays an important role. Sonority corresponds to the loudness of a sound relative to that of other sounds with the same length, stress and pitch (Ladefoged, 1993). The order of phonemes in syllables is restricted according to the sonority hierarchy. This hierarchy states that sonority has to increase from the beginning of a syllable up to the nucleus and to decrease from the nucleus up to the end of a syllable (e.g., Clements, 1990; Selkirk, 1984). According to this hierarchy, the second cluster segment in syllable-initial consonant clusters has to be more sonorous than the first cluster segment. Clements (1990) considers this sonority hierarchy to be universal excluding syllable-initial consonant clusters like /pt/, /mn/ or /fs/, for instance. In German and many other languages, the syllable-initial consonant clusters /tl/, /dl/, /tn/ and /dn/ violate the sonority hierarchy but nevertheless do also not occur syllable-initially (e.g., Clements & Keyser, 1983; Philipp, 1974; Wiese, 1996). Furthermore, for syllable-initial consonant clusters with /ʃ/ as the first segment, the sonority hierarchy is not valid (e.g., Wiese, 1986).

There are few studies that investigated the effect of phonotactic constraints on children's language acquisition (e.g., Friederici & Wessels, 1993; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993; Menn, 1971). Jusczyk and colleagues found that English and Dutch 9-month-olds preferred to listen to words that comply with phonotactically positional constraints of sounds of their native language as compared to words that violated them. In addition, the results of Friederici and Wessels (1993) indicate that Dutch 9-month-olds are sensitive to different positional constraints of sounds that hold for syllable onsets and for syllable codas. Moreover, typically developing children appear to learn words that are consistent with the inventory and positional constraints in their babbling or first words (e.g., Ferguson & Farwell, 1975; Stoel-Gammon & Cooper, 1984; Velleman & Vihman, 2002; Vihman, Ferguson, & Elbert, 1986).

The study presented here focuses on phonotactic constraints regarding sequence constraints of word-initial two-element consonant clusters. The error patterns of fronting and stopping play an important role in this study. The occurrence of these error patterns in child language have been reported for many languages focusing on consonants as singletons (see Grunwell, 1987; Hacker & Weiß, 1986; Ingram, 1976; Jakobson, 1941/1969). In contrast, the occurrence of these error patterns on consonant clusters has not received much attention. In this study, we extend the observations of fronting and stopping to consonant clusters.

The acquisition of consonant clusters is considered to make high demands on children (Chin & Dinnsen, 1992; McLeod, van Doorn, & Reed, 2001b). Producing consonant clusters implies a more difficult and complex articulatory response than the production of CV-syllables, for example (McReynolds & Elbert, 1981). Thus, every language that contains consonant clusters also comprises these same consonants as singletons but not vice versa (e.g., van de Vijver, Höhle & Ott, submitted).

Different stages in the acquisition of consonant clusters are assumed. For instance, Greenlee (1974), Ingram (1976) and Elbert and McReynolds (1979) describe the following developmental stages: (1) omission of both elements of the consonant cluster, (2) reduction to one element of the consonant cluster, (3) replacement of one element of the consonant cluster and (4) correct production of the whole consonant cluster. These developmental stages in the acquisition of consonant clusters have been found to be a robust description of children's development of two-element consonant clusters, in typical as well as in impaired development (Chin & Dinnsen, 1992; Dodd, 1995; McLeod et al., 1997; McLeod, van Doorn, & Reed, 2001a; Smit, 1993).

Research concerning the acquisition of word-initial and word-final two-element consonant clusters produced different results. Whereas some studies found that in the speech production of children with typical and impaired language development, word-final consonant clusters are produced generally earlier than word-initial consonant clusters (Dyson, 1988; Kirk & Demuth, 2005; Lléo & Prinz, 1996; McLeod et al., 1997; Watson & Scukanec, 1997), others concluded that word-initial consonant clusters are acquired earlier than word-final ones (McLeod et al., 2001a). Further studies, taking the development of cluster categories into consideration, made different observations. Some researchers found that word-initial two-element plosive clusters (e.g., /kl/) are produced correctly earlier than word-initial two-element fricative clusters (e.g., /fl/) by children with normal language development as well as by children with delayed phonological acquisition (McLeod et al., 1997; Smit, Hand, Frelinger, Bernthal, & Bird, 1990; Smith, 1973). On the other hand, it has also been observed that word-initial two-element fricative clusters are acquired earlier than word-initial two-element plosive clusters in normal language acquisition (McLeod et al., 2001a). These contrastive findings argue in favour of wide individual variation in consonant cluster development, which has been identified by many researchers (Dinnsen, 1992; Jongstra, 2003; McLeod et al., 2001a; Watson & Scukanec, 1997).

Apart from these multiple aspects relating to the acquisition of consonant clusters, the production of phonotactically inadmissible structures has not been of concern to many researchers. Children's phonotactically illegal consonant clusters were documented in the appendices of a several studies, yet the authors did not comment further on their presence (Gierut & O'Connor, 2002; Ingram, 1976; Lorentz, 1974; Smit, 1993). McLeod et al. (2001b) examined the production of phonotactically inadmissible consonant clusters. They deal with productions of the phonotactically illegal consonant clusters /bw-/ and /pw-/ in 2- and 3-year-old English-speaking children with typical language development. McLeod and colleagues interpret these results as early attempts at the production of consonant clusters. Piske (2001), who observed phonotactically inadmissible consonant clusters like /çl-/ and /kç-/ in early utterances of a typically developing German-speaking child, related the production of these consonant clusters as being due to incomplete neuro-motoric skills. The fact that such phonotactically inadmissible consonant clusters only occur over a short period of time at early stages in the speech production of children with typical development suggests that phonotactic knowledge concerning sound sequences is quickly acquired to completion (McLeod et al., 2001a).

In contrast, less is known about the effect of phonotactic constraints in the acquisition of consonant sequences in children who are delayed in phonological acquisition. Due to the fact that these children have problems in acquiring the sound system of their native language and show subsequent stages of age-inappropriate error patterns, one might expect that acquiring admissible sound sequences like consonant clusters is particularly challenging for these children. Even for normally developing children this is the hardest stage of speech development (Chin & Dinnsen, 1992; McLeod et al., 2001b).

Within this study, the effect of phonotactic constraints relating to word-initial two-element consonant clusters is examined in German-speaking children with delayed phonological acquisition. The study is based on the following reasoning: The appearance of the error pattern fronting (e.g., *Kuh* "cow" /ku:/ → [tu:], *Gurke* "cucumber" /gʊɐkə/ → [dʊɐkə]) in the word-initial consonant clusters /kl/ (e.g., *Kleid* "dress"), /kn/ (e.g., *Knopf* "button"), /gl/ (e.g., *Glas* "glass"), and /gn/ (e.g., *Gnu* "gnu") would result in productions of the word-initial consonant clusters /tl/ and /tn/, respectively /dl/ and /dn/. Such clusters violate the German phonotactic constraints (e.g., Wiese, 1996). The same holds for the error pattern stopping (e.g., *Schaf* "sheep" /ʃa:f/ → [ta:f]) in the word-initial consonant clusters /ʃl/ (e.g., *Schlange* "snake"), and /ʃn/ (e.g., *Schnecke* "snail") which would result in productions of the word-initial consonant clusters /tl/ and /tn/, which again are not allowed by German phonotactic constraints.

By eliciting words with these consonant clusters it can be observed whether or not children with the error patterns fronting and stopping obey the phonotactic constraints of sound sequences of their native language. With respect to the error patterns on singletons, the question is whether children with phonological delay show associated delays in other phonological areas like phonotactics and production of consonant clusters as well. Do the children have a specific or a more general delay in their phonological development?

A picture naming task and a word repetition task were selected to elicit words from the children. It has been shown that the occurrence of the error patterns stopping and fronting as well as the overall accuracy of productions of word-initial consonant clusters is not influenced by the sampling technique selected (Dyson & Robinson, 1987; McLeod, Hand, Rosenthal, & Hayes, 1994; Morrison & Shriberg, 1992). The reason for using two tasks was to increase the probability of eliciting at least one production of each target word by each child.

Method

Participants

For this study, 12 German-speaking children (eight boys, four girls) with delayed phonological acquisition were investigated. (This does not mean that their acquisition was disordered, see Barlow, 1997; Morrissette, Dinnsen, & Gierut, 2003, for a discussion of this point.) The children ranged in age from 4;2 to 8;6 (mean age 5;1). All the children had restricted phoneme inventories in their expressive modality and at least one developmental error pattern that was inappropriate for their chronological age. This diagnosis was obtained through spontaneous speech samples and a standardized German assessment for developmental language disorders (Fox & Dodd, 2001; Kauschke & Siegmüller, 2002).

In order to include the participants in this study it was necessary that they had inappropriate fronting or stopping error patterns for their age. All children met this condition. Thus, seven of them had a regular appearance of the error pattern fronting (e.g., *Kuh* "cow" /ku:/ → [tu:]) which disappears around age 3;11 in normal language development in German. The speech production of the other five children was characterized by a regular appearance of the error pattern stopping (e.g., *Schaf* "sheep" /ʃa:f/ → [ta:f]) which disappears around age 3;0 in typically developing German children (e.g., Fox & Dodd, 2001). None of the participants had known hearing disorders, neurological abnormalities, nor organic or cognitive impairments. At the time of investigation all children received speech therapy because of their phonological delays.

Materials

All target words included in the study were nouns. They were chosen with regard to their phonological structure. First, a stimulus set with German words containing initial single consonants /k/ (e.g., *Kuh* "cow"), /g/ (e.g., *Gurke* "cucumber"), and /ʃ/

(e.g., *Schaf* "sheep") was employed to elicit words from the children in which the fronting or stopping error patterns were obvious—so the words with initial /k/ and /g/ were critical for the children with fronting, the words with initial /ʃ/ were critical for the children with stopping. Six words with initial /g/, 11 words with initial /k/ and 11 words with initial /ʃ/ were chosen.

Second, a stimulus set with words containing initial consonant clusters was chosen for which the application of the error patterns would lead to the production of phonotactically inadmissible consonant clusters. Hence, for the children with fronting, words containing initial consonant clusters /kl/ (e.g., *Kleid* "dress"), /kn/ (e.g., *Knopf* "button"), /gl/ (e.g., *Glas* "glass"), or /gn/ (e.g., *Gnu* "gnu") were selected in which the application of the fronting process would lead to production of the phonotactically illegal clusters /tl-/ (e.g., *Kleid* "dress" /klait/ → [*tlait]), /tn-/ (e.g., *Knopf* "button" /knɔpf/ → [*tnɔpf]), /dl-/ (e.g., *Glas* "glass" /gla:s/ → [*dla:s]), and /dn-/ (e.g., *Gnu* "gnu" /gnu:/ → [*dnu:]). For the children with stopping words containing initial consonant clusters /ʃl/ (e.g., *Schlange* "snake"), and /ʃn/ (e.g., *Schnecke* "snail") were chosen in which the application of the stopping process would lead to production of the phonotactically illegal clusters /tl-/ (e.g., *Schlange* "snake" /ʃlaŋə/ → [*tlaŋə]), and /tn-/ (e.g., *Schnecke* "snail" /ʃnɜkə/ → [*tnɜkə]). The whole stimulus set of words with initial consonant clusters consisted of 17 words with initial /kl/, /kn/, /gl/ and /gn/ and 11 words with initial /ʃl/ and /ʃn/. The words with initial single consonants and with initial consonant clusters were grouped with respect to number of syllables, compound, gender and frequency (CELEX lexical database, Baayen, Pipenbrock, & Gulikers, 1995) as seen in the Appendix.

For the children with fronting 34 words were critical (words with initial /k/, /g/, /kl/, /kn/, /gl/ and /gn/), for the children with stopping 22 words were critical (words with initial /ʃ/, /ʃl/ and /ʃn/). The difference in number was due to the fact that only words whose referents were visualizable and that were assumed to be known by 4-year-old children could be used. These criteria restricted the stopping set more heavily than the fronting set.

In order to elicit the target words from the children, a picture naming task and a word repetition task were created. The pictures for the picture naming task were either hand-drawn, chosen from a clipart software library (Kelly Data GmbH, 2000) or from a German standardized language assessment (Kauschke & Siegmüller, 2002). Every picture was presented to the child on a single sheet of paper.

Procedure

The participants were tested individually in a quiet room in their familiar surroundings. The picture naming task was carried out first. During this task, all children had to name all 56 pictures of all target words, ensuring that every child was examined with the same number of items.

Pictures which described words containing initial single consonants and words containing initial consonant clusters were presented in a mixed random order. The pictures were presented one after the other and the children were asked to name them. If a child was not able to name a picture, the experimenter helped him in the following way: (a) presenting a semantic circumscription of the word (e.g., *Klavier*: *Musik machen, viele Tasten* "piano: to play music, many keys"), (b) giving two words for selection, (e.g., *Klavier*: *Klavier-Geige* "piano: piano-violin"), (c) saying the word for repetition. The words that children uttered after the help of (b) and (c) were not analysed as naming reactions but as elicited imitation.

In the word repetition task, the children were asked to repeat the word the experimenter said. In order to avoid a pure and isolated repetition, the task was embedded in a game called "All monkeys parrot!" in which the spoken words had to be repeated by a toy monkey as well as by the child. Depending on individual age and performance level the investigation of a single child took between 30 and 60 minutes over one or two sessions. The utterances of the children were recorded on a tape and also written down by the experimenter during the experiment.

Results

Coding the data and considering answer categories

All notes made during the experiment were compared with the recordings. Using the International Phonetic Alphabet (IPA) as given for German in Drosdowski, Müller, Scholze-Stubenrecht and Wermke (1990), the notes were transcribed phonetically.

In the picture naming task, the children named the pictures with the intended word in 60.7% of the cases. In the word repetition task, all words were repeated by every child. For the statistical analysis, the productions were pooled in one data set, regardless of whether they were responses from the picture naming task or the repetition task. The responses were assigned to different answer categories (see Table I).

Results for all children

The statistical analysis of the children's productions involved comparisons within each of the two word sets (words with critical initial singletons, words with critical initial consonant clusters) and between these two sets. Because the data was not normally distributed, the non-parametric Wilcoxon test for statistical comparisons was used.

When the critical phonemes appeared as single consonants in word-initial positions (fronting: /k/ and /g/; stopping: /ʃ/), the children showed the error patterns fronting or stopping in most cases, although correct productions also occurred. Replacements by other phonemes occurred very rarely (see Figure 1).

The statistical comparison showed that the error patterns occurred significantly more often than correct productions for the initial phonemes ($Z = -2.957$, $p < .01$).

For the critical word-initial consonant clusters (fronting: /kl/, /kn/, /gl/ and /gn/; stopping: /ʃl/ and /ʃn/) correct productions occurred as well as reductions to one segment and phonotactically legal replacements of the first cluster segments. The error patterns resulting in phonotactically illegal consonant clusters occurred to a smaller extent. Occasionally, whole consonant clusters were omitted (see Figure 2). In the words containing the critical word-initial consonant clusters, the children showed significantly more correct productions of the two cluster segments than the error patterns within these clusters ($Z = -2.313$, $p < .05$). Furthermore, phonotactically legal replacements of the first cluster phonemes, i.e., of the critical phonemes, occurred significantly more often than the error patterns ($Z = -2.293$, $p < .05$). The comparison between cluster reductions to one phoneme and the error patterns revealed no significant difference, although a tendency arose indicating that the clusters were reduced more often to one phoneme than they were changed by the error patterns ($Z = -1.785$, $p = .074$).

In the next step, responses to words with initial single consonants were compared with those to words with initial consonant clusters. The error patterns occurred significantly more often in the critical phonemes as singletons than in consonant clusters ($Z = -3.061$, $p < .01$). The comparison of correct productions revealed no significant difference ($Z = -1.423$, $p = .155$), although the mean percentages indicate a tendency that the critical sounds were produced correctly more often in clusters than as singletons.

Furthermore, the kinds of reductions occurring in consonant clusters were analysed in detail (see Figure 3). It was observed that no child with stopping reduced /ʃ/ clusters to this critical phoneme. Only one child with fronting reduced a consonant cluster to the first critical segment. This child reduced initial /kn/ in the item *Knäuel* "ball of wool" /knɔyəl/ to single /k/. Instead, reductions and replacements to /t/ and /d/ appeared frequently for children with stopping and for children with fronting. There was a marginally significant tendency that the reductions and replacements to /t/ and /d/ occurred more often compared to reductions to the second segment /l/ ($Z = -1.782$, $p = .075$) but not compared to reductions to the second segment /n/ ($Z = -.711$, $p = .477$).

While comparing only reductions to the second cluster segments, it was found that reductions to /n/ occurred significantly more often than reductions to /l/ ($Z = -2.201$, $p < .05$). Reductions to /l/ were observed for only one child with stopping, e.g., *Schlauch* "hose" /ʃlaux/ → [laux]. No child with fronting reduced plosive-liquid clusters (/kl/, /gl/) to the liquid /l/.

Table I. Answer categories.

Stimulus	Answer category	Example for fronting
Initial single consonants	error pattern (fronting, stopping)	/k/ → /t/
	correct production	/k/ → /k/
	other replacement	/k/ → /p/
Initial consonant clusters	error pattern (fronting, stopping)	/kl/ → /tl/*
	correct production	/kn/ → /kn/
	cluster reduction	
	to the first cluster segment	/kn/ → /k/
	to the second cluster segment	/kn/ → /n/
	and replacement to /t/ or /d/	/kl/ → /t/
	to another phoneme	/kl/ → /p/
	phonotactically legal replacement	
	of the first cluster segment	/kl/ → /pl/
	of the second cluster segment	–[1]
	complete omission	/kl/ → /ø/

*Violation of German phonotactic constraints.
[1]No occurrence.

Children with fronting and children with stopping

In a further analysis, words with initial single consonants and words with initial consonant clusters were compared separately for the children with fronting and for those with stopping. The data corpus was comprehensive enough to do a statistical comparison referring to the number of correct

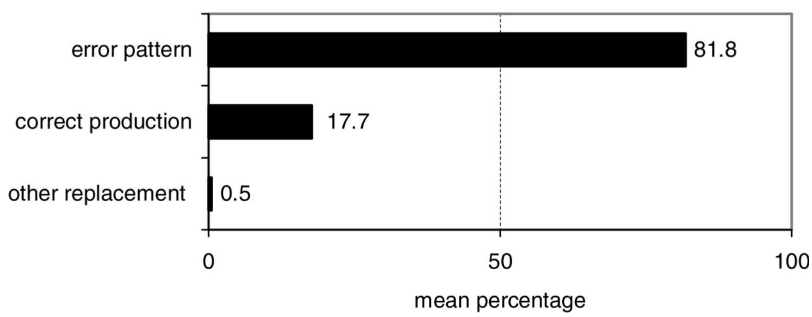


Figure 1. Distribution of responses in the words containing initial single consonants for all children.

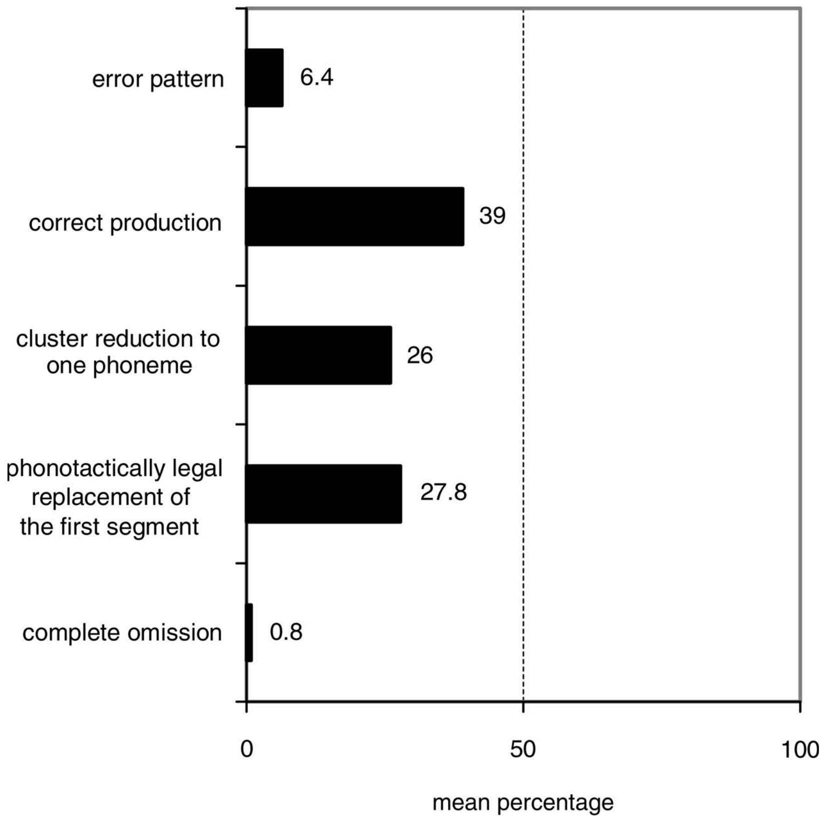


Figure 2. Distribution of responses in the words containing initial consonant clusters for all children.

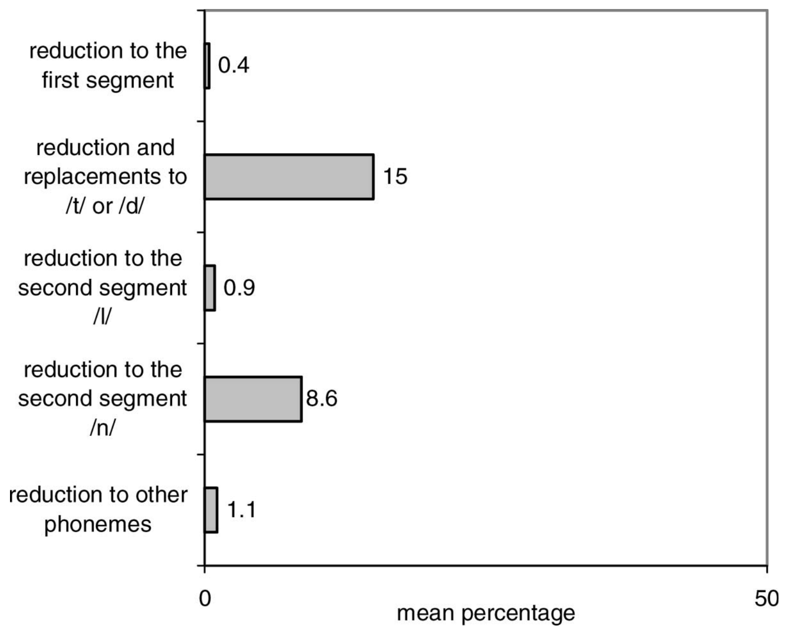


Figure 3. Subdivision of cluster reductions to one phoneme for all children.

productions, i.e., nearly all children have shown correct productions. For the children with fronting, the results revealed that the critical phonemes (e.g., /k/, /g/) were produced correctly significantly more often in clusters than in words in which they appeared as single consonants ($Z = -2.197$, $p < .05$). For three of these children, it was even observed that the critical phonemes were never produced correctly when they appeared as singletons but when they were embedded in consonant clusters. For the children with stopping no such difference was observed, the data revealed an opposite tendency which was not significant ($Z = -1.461$, $p = .144$) (see Figure 4).

Discussion

The main result of our study is that the children with the developmental error pattern of fronting showed

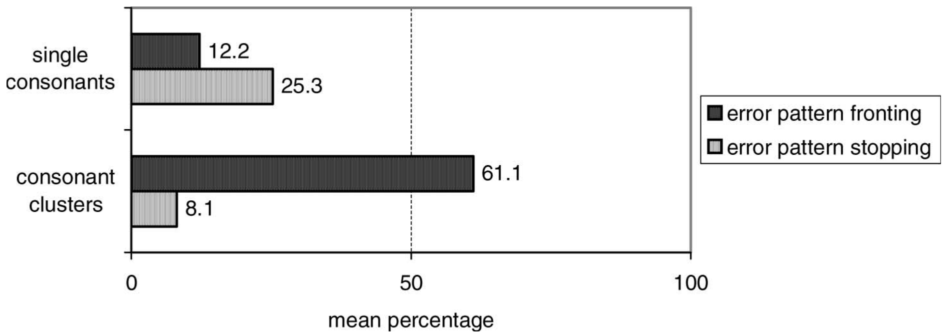


Figure 4. Correct productions.

this pattern more often when the critical phonemes /k/ and /g/ appeared as single consonants than when they appeared in consonant clusters. Thus, the children only rarely produced the phonotactically illegal word onsets /tl-/, /tn-/, /dl-/ and /dn-/ and did indeed correctly produce the critical phonemes /k/ and /g/ in word-initial consonant clusters. This correct production in consonant clusters occurred more than twice as often as in words in which the critical phonemes appeared as single consonants.

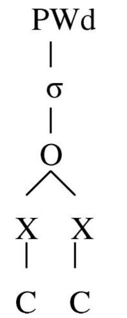
That the children with fronting as well as the children with stopping eliminated the production of phonotactically illegal consonant clusters is also evidenced by additional observations: First, the error patterns occurred more often than correct productions in words with initial single consonants, whereas in words with initial consonant clusters the opposite pattern appeared. Second, the first segments of the consonant clusters were replaced by phonotactically legal consonant clusters (e.g., stopping: /ʃl-/ → [pl-]) significantly more often than by phonotactically illegal consonant clusters. Finally, the consonant clusters were often reduced to one phoneme.

The results strongly indicate that German children with delayed phonological acquisition are affected by phonotactic constraints concerning restrictions of word-initial consonant clusters. The utterances of these children are influenced by phonotactic restrictions regarding phoneme combination of the target language German.

Referring to kinds of cluster reductions, one finding of the study was that reductions to the second segment /n/ occurred more often than to the second segment /l/ including that no plosive-liquid cluster was reduced to the liquid /l/. This finding is compatible with observations from children with typical language development, where cluster reductions to the second segment occur more often in plosive-nasal clusters (/kn/, /gn/) than in plosive-liquid clusters (/kl/, /gl/) (Fox, 2003; Romonath, 1991). In contrast to plosive-nasal clusters plosive-liquid clusters were reduced more often to the least sonorous consonant, i.e., to the plosive (Lléo & Prinz, 1996; Ohala, 1999). We also observed this for the children with phonological delays.

The children with fronting correctly produced the critical initial consonant clusters /kl/, /kn/, /gl/ and /gn/ significantly more often than /k/ and /g/ as simple word onsets. In contrast, children with stopping did not show more correct productions of /ʃ/ in the consonant clusters than as singletons. This finding indicates that word-initial /ʃ/-clusters have another internal structure than word-initial /k/- and /g/-clusters. This supports phonological theories (Fikkert, 1994; Giegerich, 1992; Wiese, 1996) that assume that both elements of obstruent-clusters (e.g., /kl/, /kn/) are located in the onset, see (1), whereas the /ʃ/ within /ʃ/-initial clusters is not part of the onset but is located in an extrasyllabic position, see (2).

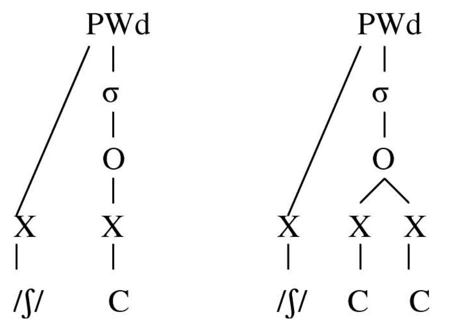
(1) obstruent-initial clusters: branching onset



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

(2) /ʃ/-initial clusters: appendix + onset

a. two-member clusters b. three-member clusters



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

This assumption is supported by several specific features of German /ʃ/-initial clusters. First, word-initial three-member clusters, like /ʃpr-/, /ʃtr-/ and /skl-/, e.g., *Sprache* "language", *Straße* "street" and *Sklave* "slave", are always /ʃ/- or /s/-initial. If grammar permits onsets to be at most binary, sequences of the three-member-shape /ʃ/ + plosive + liquid and /s/ + plosive + liquid must have the structure in (2b) (Goad & Rose, 2004). Second, in /ʃ/-sonorant clusters (/ʃl/, /ʃn/) the absence of the *place identity effect* is observed, i.e., both elements have the same articulator [+coronal]: If these clusters were organized as branching onsets, they would violate the constraint OCP[POA] (van de Vijver et al., submitted), see (3). Third, /ʃ/-initial clusters do not consist of branching onsets because some of them, for example, /ʃ/-plosive clusters like /ʃt-/ in *Stuhl* "chair", violate the sonority hierarchy (e.g., Wiese, 1986). Finally, for typical language acquisition it has been described that /ʃ/-initial clusters are acquired later than obstruent-initial clusters (e.g., Elsen, 1991). Our findings indicate that /ʃ/-initial clusters also behave differently in language acquisition of children with delayed phonological acquisition.

Another intriguing result of our study is the finding that for the children with delayed phonological development and fronting, complex syllable structures including consonant clusters were more likely to be produced correctly than singleton onsets. In order to discuss this result, Optimality Theory (henceforth OT) was consulted (McCarthy & Prince, 1993; Prince & Smolensky, 1993). OT has been applied to explain a number of issues in phonological acquisition. An OT grammar consists of a set of universal, violable constraints on output representations, ranked in a language-specific way. During language acquisition children rank constraints. Along the way children may achieve stages of constraint rankings which are not counterparts of the adult language. Finally, the children reach the constraint ranking of the target language and therefore produce output forms that correspond to the adult ones. The following constraints are relevant for analysing the data of the children with fronting:

(3) Constraints:
  a. OCP[POA]
     Consonants in an onset cluster should not share place of articulation features (van de Vijver et al., submitted).
  b. *ONSET[POA-DORSAL
     No word-initial dorsals (van de Vijver et al., submitted).
  c. FAITH
     Inputs and outputs should correspond to each other (Levelt, Schiller, & Levelt, 2000, p. 244).

OCP[POA] and *ONSET[POA-DORSAL are structural constraints. They demand outputs to be structurally unmarked. Unmarked structures are valid cross-linguistically and early observed in language acquisition, e.g., coronal segments like /t/ and open CV-syllables are structurally unmarked (Smolensky, 1996). FAITH is a faithfulness constraint and demands outputs to be faithful to their inputs whether these are structurally marked or not (Levelt et al., 2000; Levelt & van de Vijver, 2004; Prince & Smolensky, 1993).

The three constraints mentioned in (3) can establish the optimal candidates for words containing an initial single /k/ and for words containing initial consonant clusters with /k/ as the first segment, see Tables II and III. An asterisk (*) indicates violations of constraints by candidates. An asterisk followed by an exclamation mark (*!) indicates a fatal violation and this indicates that the candidate is not optimal for output. The pointing finger marks the winning or most harmonic candidate, i.e., the output form. Shading under a certain constraint indicates that this constraint is not crucial in determining the optimal output.

The constraint with the most effect resides at the highest position of the constraint hierarchy, i.e., is represented as the left most position in a Table as seen in Tables II and III. In Tables II and III the constraint OCP[POA] is the one with the most effect.

The optimal output candidates in Table II are *Kuh* /ku:/, *Kleid* /klait/ and *Knopf* /knɔpf/. In German, such a ranking can be assumed for the adult production of all words with initial /k/, /kl/ and /kn/. For children who already produce /k/-, /kl/- and /kn/-initial words correctly, it can be assumed that they have already acquired this target ranking of constraints.

Since the children of this study with fronting error pattern have shown a production pattern diverging from adult language, i.e., /ku:/ → [tu:], but /klait/ → [klait] and /knɔpf/ → [knɔpf], another ranking of the constraints has to be responsible for this output pattern. Table III presents the ranking of constraints for the production patterns of the children with delayed phonological acquisition and with fronting.

As can be seen in Table III, for an input word containing initial single /k/ (e.g., *Kuh* "cow" /ku:/), the candidate which incurs the least serious violations of the hierarchy of constraints is the word with initial /t/, i.e., /tu:/. Among input words containing the initial consonant clusters /kl/ and /kn/, the winning candidates are the target ones. When comparing the constraint ranking of the phonologically delayed children with the one of the target language, it becomes obvious that *ONSET[POA-DORSAL is ranked higher than FAITH in the ranking of the children with delayed phonological acquisition. The faithfulness constraint FAITH has the lowest ranking. This fact may also provide an explanation to why the children with delayed phonological acquisition and

Table II. Constraint ranking in target language.

	OCP[PoA]	Faith	*Onset[PoA-Dorsal
/ku:/ *Kuh* "cow"			
☞ /ku:/			*
/tu:/		*!	
/klait/ *Kleid* "dress"			
☞ /klait/			*
/tlait/	*!	*	
/knɔpf/ *Knopf* "button"			
☞ /knɔpf/			*
/tnɔpf/	*!	*	

Note: * = violation of constraints. *! = fatal violation (not optimal for output). ☞ = winning or most harmonic candidate (i.e., the output form).

Table III. Constraint ranking in the children with delayed phonological acquisition and with the error pattern fronting.

	OCP[PoA]	*Onset[PoA-Dorsal	Faith
/ku:/ *Kuh* "cow"			
/ku:/		*!	
☞ /tu:/			*
/klait/ *Kleid* "dress"			
☞ /klait/		*	
/tlait/	*!		*
/knɔpf/ *Knopf* "button"			
☞ / knɔpf /		*	
/tnɔpf/	*!		*

Note: * = violation of constraints. *! = fatal violation (not optimal for output). ☞ = winning or most harmonic candidate (i.e., the output form).

fronting prefer /t/ over /k/ in word-initial single onsets but not in word-initial consonant clusters. Since it is assumed that initially faithfulness constraints are ranked below structural constraints in typical language acquisition (e.g., Gnanadesikan, 1995; Levelt et al., 2000) for the children with phonological delays in our study it can be assumed that they are situated in such an initial stage. Therefore, the OT-analysis provides evidence for a similar developmental trajectory of language acquisition in children with typical development and in children with phonological delays.

The observation that children with delayed phonological acquisition and fronting produce dorsals in consonant clusters more often correctly than as singletons may have clinical relevance to speech-language pathology. Words with the initial consonant clusters /kl/, /kn/, /gl/ and /gn/ are promising candidates to elicit the critical dorsal phonemes from the children during treatment.

As stated above, the children with stopping did not show the pattern of correctly producing consonant clusters more often than singleton onsets and therefore behave differently from the children with fronting. Instead, they showed great variation producing the /ʃ/-initial clusters that did not allow an OT-analysis that applies to all stopping children as one group. This circumstance reinforces the remarks that /ʃ/-initial clusters have another structure than plosive-initial clusters and are acquired differently from them.

Conclusion

In conclusion, the results of this study strongly suggest that phonotactic constraints concerning sequence constraints in word-initial consonant clusters have effects on German children with delayed phonological acquisition. Phonotactic constraints effect the word production of these children and influence the occurrence of their developmental error patterns which characterize their spontaneous speech.

German children with phonological delays show similar approaches as children with normal language development. The results of this study provide evidence for a similar developmental trajectory, i.e., in handling word-initial consonant clusters, e.g., producing obstruent-initial and /ʃ/-initial clusters and reducing these clusters, and with regard to the ranking of structural and faithfulness constraints.

Further studies have to be conducted to answer questions such as how children with delayed phonological development behave differently on consonant-liquid and consonant-nasal clusters considering the marked aspect of plosive-nasal clusters. Moreover, further research should address the questions of how children with delayed phonological acquisition rank constraints, in order to reach the constraint ranking of the target language, and what paths they take in their way to that ranking.

References

Baayen, R. H., Pipenbrock, R., & Gulikers, L. (1995). *The CELEX lexical database (CD-ROM)*. Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania.

Barlow, J. A. (1997). A constraint-based account of syllable onsets: Evidence from developing systems. Unpublished doctoral dissertation, Indiana University.

Chin, S. B., & Dinnsen, D. A. (1992). Consonant clusters in disordered speech: Constraints and correspondence patterns. *Journal of Child Language*, *19*, 259 – 285.

Clements, G. N., & Keyser, S. J. (1983). *CV phonology. A generative theory of the syllable.* Cambridge, MA: MIT Press.

Clements, G. N. (1990). The role of the sonority cycle in core syllabification. In J. Kingston & M. E. Beckman (Eds.), *Papers in laboratory phonology 1: Between the grammar and the physics of speech* (pp. 283 – 333). Cambridge: Cambridge University Press.

Dinnsen, D. A. (1984). *Methods and empirical issues in analyzing functional misarticulation.* Rockville, MD: ASHA.

Dinnsen, D. A. (1992). Variation in developing and fully developed phonetic inventories. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 191 – 210). Timonium, MD: York Press.

Dodd, B. (1995). *The differential diagnosis and treatment of children with speech disorder.* London: Whurr Publishers.

Drosdowski, G., Müller, W., Scholze-Stubenrecht, W., & Wermke, M. (1990). *Duden—Das Aussprachewörterbuch: Wörterbuch der deutschen Standardaussprache.* Mannheim: Bibliographisches Institut.

Dyson, A. T., & Robinson, T. W. (1987). The effect of phonological analysis procedure on the selection of potential remediation targets. *Language, Speech, and Hearing Services in Schools*, *18*, 364 – 377.

Dyson, A. T. (1988). Phonetic inventories of 2- and 3-year-old children. *Journal of Speech and Hearing Disorders*, *53*, 89–93.

Elbert, M., & Gierut, J. A. (1986). *Handbook of clinical phonology: Approaches to assessment and treatment.* Austin, TX: Pro-Edition.

Elbert, M., & McReynolds, L. V. (1979). Aspects of phonological acquisition during articulation training. *Journal of Speech and Hearing Disorders*, *64*, 459–471.

Elsen, H. (1991). *Erstspracherwerb: Der Erwerb des deutschen Lautsystems.* Wiesbaden: Deutscher Universitätsverlag.

Ferguson, C. A., & Farwell, C. B. (1975). Words and sounds in early language acquisition. *Language*, *51*, 419–439.

Fikkert, P. (1994). *On the acquisition of prosodic structure.* Dordrecht: ICG Printing.

Fikkert, P., Penner, Z., & Wymann, K. (1998). Das Comeback der Prosodie. Neue Wege in der Diagnose und Therapie von phonologischen Störungen. *LOGOS Interdisziplinär*, *6*, 84–97.

Fox, A., & Dodd, B. (2001). Phonologically disordered German-speaking children. *American Journal of Speech-Language Pathology*, *10*, 291–307.

Fox, A. (2003). *Kindliche Aussprachestörungen.* Idstein: Schulz-Kirchner-Verlag.

Friederici, A. D., & Wessels, J. M. I. (1993). Phonotactic knowledge and its use in infant speech perception. *Perception and Psychophysics*, *54*, 287–295.

Giegerich, H. (1992). *English phonology: An introduction.* Cambridge: Cambridge University Press.

Gierut, J. A., & O'Connor, K. M. (2002). Precursors to onset clusters in acquisition. *Journal of Child Language*, *29*, 495–517.

Gierut, J. A. (1998). Treatment efficacy: Functional phonological disorders in children. *Journal of Speech, Language, and Hearing Research*, *41*, 85–100.

Gnanadesikan, A. (1995). *Markedness and faithfulness constraints in child phonology.* University of Massachusetts, Amherst.

Goad, H., & Rose, Y. (2004). Input elaboration, head faithfulness and evidence for representation in the acquisition of left-edge clusters in West Germanic. In R. Kager, J. Pater, & W. Zonneveld (Eds.), *Fixing priorities: Constraints in phonological acquisition* (pp. 109–157). Cambridge: Cambridge University Press.

Greenlee, M. (1974). Interacting processes in the child's acquisition of stop-liquid clusters. *Papers and Reports on Child Language Development, Stanford University*, *7*, 85–100.

Grunwell, P. (1987). *Clinical phonology.* London: Chapman & Hall.

Hacker, D., & Weiß, K.-H. (1986). *Zur phonemischen Struktur funktioneller Dyslalien.* Oldenburg: Verlag Arbeiterwohlfahrt.

Hacker, D. (1999). Phonologie. In S. Baumgartner & I. Füssenich (Eds.), *Sprachtherapie mit Kindern* (pp. 13–62). München: Ernst Reinhardt Verlag.

Ingram, D. (1976). *Phonological disability in children.* London: Whurr.

Jakobson, R. (1941/1969). *Kindersprache, Aphasie und allgemeine Lautgesetze.* Frankfurt/Main: Edition Suhrkamp.

Jongstra, W. (2003). *Variation of reduction strategies of Dutch word-initial consonant clusters.* PhD dissertation, University of Toronto.

Jusczyk, P., Friederici, A. D., Wessels, J. M. I., Svenkerud, V., & Jusczyk, A. M. (1993). Infants' sensitivity to the sound patterns of native language words. *Journal of Memory and Language*, *32*, 402–420.

Kauschke, C., & Siegmüller, J. (2002). *Patholinguistische Diagnostik bei Sprachentwicklungsstörungen.* Jena: Urban & Fischer.

Kelly Data GmbH (2000). *333.333 Cliparts (CD-ROM).* Königswinter: Tandem Verlag.

Kirk, C., & Demuth, K. (2005). Asymmetries in the acquisition of word-initial and word-final consonant clusters. *Journal of Child Language*, *32*, 709–734.

Ladefoged, P. (1993). *A course in phonetics.* New York: Harcourt Brace.

Leonard, L. B. (1985). Unusual and subtle phonological behaviour in the speech of phonologically disordered children. *Journal of Speech and Hearing Disorders*, *50*, 4–13.

Levelt, C. C., & van de Vijver, R. (2004). Syllable types in cross-linguistic and developmental grammars. In R. Kager, J. Pater, & W. Zonneveld (Eds.), *Fixing priorities: Constraints in phonological acquisition* (pp. 204–218). Cambridge: Cambridge University Press.

Levelt, C. C., Schiller, N. O., & Levelt, W. J. (2000). The acquisition of syllable types. *Language Acquisition*, *8*, 237–264.

Lléo, C., & Prinz, M. (1996). Consonant clusters in child phonology and the directionality of syllable structure assignment. *Journal of Child Language*, *23*, 31–56.

Lorentz, J. (1974). A deviant phonological system of English. *Papers and Reports on Child Language Development*, *8*, 55–64.

McCarthy, J. J., & Prince, A. S. (1993). *Prosodic morphology I: Constraint interaction and satisfaction.* New Brunswick: University of Massachusetts, Amherst & Rutgers University.

McLeod, S., Hand, L., Rosenthal, J. B., & Hayes, B. (1994). The effect of sampling condition on children's productions of consonant clusters. *Journal of Speech and Hearing Research*, *37*, 868–882.

McLeod, S., van Doorn, J., & Reed, V. A. (1997). Realizations of consonant clusters by children with phonological impairment. *Clinical Linguistics and Phonetics*, *11*, 85–113.

McLeod, S., van Doorn, J., & Reed, V. A. (2001a). Consonant cluster development in 2-year-olds: General trends and individual difference. *Journal of Speech, Language, and Hearing Research*, *44*, 1144–1171.

McLeod, S., van Doorn, J., & Reed, V. A. (2001b). Normal acquisition of consonant clusters. *American Journal of Speech-Language Pathology*, *10*, 99–110.

McReynolds, L. V., & Elbert, M. (1981). Generalization of correct articulation in clusters. *Applied Psycholinguistics*, *2*, 119–132.

Menn, L. (1971). Phonotactic rules in beginning speech. *Lingua*, *26*, 225–251.

Morrison, J. A., & Shriberg, L. D. (1992). Articulation testing versus conversational speech sampling. *Journal of Speech and Hearing Research*, *35*, 259–273.

Morrissette, M. L., Dinnsen, D. A., & Gierut, J. A. (2003). Markedness and context effects in the acquisition of place features. *Canadian Journal of Linguistics/Revue canadienne de linguistique*, *48*, 329–355.

Ohala, D. (1999). The influence of sonority on children's cluster reductions. *Journal of Communication Disorders*, *32*, 397–422.

Philipp, M. (1974). *Phonologie des Deutschen.* Stuttgart: Kohlhammer.

Piske, T. (2001). *Artikulatorische Muster im frühen Laut- und Lexikonerwerb.* Tübingen: Gunter Narr Verlag.

Prince, A. S., & Smolensky, P. (1993). *Optimality theory: Constraint interaction in generative grammar.* New Brunswick: Rutgers University & University of Colorado.

Romonath, R. (1991). *Phonologische Prozesse an sprachauffälligen Kindern.* Berlin: Edition Marhold im Wissenschaftsverlag Spiess.

Selkirk, E. O. (1984). *Phonology and syntax. The relation between sound and structure.* Cambridge, MA: MIT Press.

Smit, A. B. (1993). Phonologic error distributions in the Iowa-Nebraska articulation norms project: Word-initial consonant clusters. *Journal of Speech and Hearing Research*, *36*, 931–947.

Smit, A. B., Hand, L., Frelinger, J. J., Bernthal, J. E., & Bird, A. (1990). The Iowa articulation norms project and its Nebraska replication. *Journal of Speech and Hearing Disorders*, *55*, 779–798.

Smith, N. V. (1973). *The acquisition of phonology: A case study.* Cambridge: Cambridge University Press.

Smolensky, P. (1996). On the comprehension/production dilemma in child language. *Linguistic Inquiry*, *27*, 720–731.

Stoel-Gammon, C., & Cooper, J. A. (1984). Patterns of early lexical and phonological development. *Journal of Child Language*, *11*, 247–271.

Storkel, H. L., & Rogers, M. A. (2000). The effect of probabilistic phonotactics on lexical acquisition. *Clinical Linguistics and Phonetics*, *14*, 407–425.

Storkel, H. L. (2001). Learning new words: Phonotactic probability in language development. *Journal of Speech, Language, and Hearing Research*, *44*, 1321 – 1337.

Storkel, H. L. (2004). The emerging lexicon of children with phonological delays: Phonotactic constraints and probability in acquisition. *Journal of Speech, Language, and Hearing Research*, *47*, 1194 – 1212.

van de Vijver, R., Höhle, B., & Ott, S. (submitted). Emerging dorsals in simple and complex onsets. In C. Féry, R. van de Vijver, & F. Kügler (Eds.).

Velleman, S., & Vihman, M. M. (2002). Whole-word phonology and templates: Trap, bootstrap or some of each? *Language, Speech, and Hearing Services in Schools*, *33*, 9 – 23.

Vihman, M. M., Ferguson, C. A., & Elbert, M. (1986). Phonological development from babbling to speech: Common tendencies and individual differences. *Applied Psycholinguistics*, *7*, 3 – 40.

Watson, M. M., & Scukanec, G. P. (1997). Profiling the phonological abilities of 2-year-olds: A longitudinal investigation. *Child Language Teaching and Therapy*, *13*, 3 – 14.

Wiese, R. (1986). Schwa and the structure of words in German. *Linguistics*, *24*, 697 – 724.

Wiese, R. (1996). *The phonology of German.* Oxford: Clarendon Press.

Zamuner, T., Gerken, L. A., & Hammond, M. (2004). Phonotactic probabilities in young children's speech production. *Journal of Child Language*, *31*, 515 – 536.

Appendix

Stimuli of the picture naming task and the word repetition task.

		Item	Syllable	Compound	Gender	Frequency[1]
Stimuli for fronting	1	Koch (cook)	1	no	masculine	–[2]
	2	Korb (basket)	1	no	masculine	7
	3	Kamm (comb)	1	no	masculine	5
	4	Kuh (cow)	1	no	feminine	12
	5	Kette (necklace)	2	no	feminine	14
	6	Kuchen (cake)	2	no	masculine	15
	7	Kamel (camel)	2	no	neuter	2
	8	Koffer (suitcase)	2	no	masculine	17
	9	Käse (cheese)	2	no	masculine	9
	10	Kühlschrank (refrigerator)	2	yes	masculine	5
	11	Kopftuch (headscarf)	2	yes	neuter	3
	12	Gold (gold)	1	no	neuter	5
	13	Geist (ghost)	1	no	masculine	43
	14	Gabel (fork)	2	no	feminine	2
	15	Gürtel (belt)	2	no	masculine	3
	16	Gurke (cucumber)	2	no	feminine	2
	17	Gießkanne (watering-can)	3	yes	feminine	–
	18	Kleid (dress)	1	no	neuter	32
	19	Clown (clown)	1	no	masculine	2
	20	Klammer (peg)	2	no	feminine	12
	21	Klavier (piano)	2	no	neuter	12
	22	Kleeblatt (cloverleaf)	2	yes	neuter	–
	23	Knie (knee)	1	no	neuter	9
	24	Knopf (button)	1	no	masculine	3
	25	Knäuel (ball of wool)	2	no	neuter	–
	26	Knoten (knot)	2	no	masculine	14
	27	Knochen (bone)	2	no	masculine	9
	28	Knallbonbon (cracker)	3	yes	masculine	–
	29	Glas (glass)	1	no	neuter	49
	30	Glocke (bell)	2	no	feminine	–
	31	Glatze (bald head)	2	no	feminine	–
	32	Globus (globe)	2	no	masculine	2
	33	Glühbirne (electric bulb)	3	yes	feminine	24
	34	Gnu (gnu)	1	no	neuter	–
Stimuli for stopping	1	Schaf (sheep)	1	no	neuter	2
	2	Schuh (shoe)	1	no	masculine	22
	3	Schal (scarf)	1	no	masculine	–
	4	Ski (ski)	1	no	masculine	5
	5	Schere (scissors)	2	no	feminine	7
	6	Schürze (apron)	2	no	feminine	3
	7	Schüssel (bowl)	2	no	feminine	2
	8	Schaukel (swing)	2	no	feminine	–
	9	Schatten (shadow)	2	no	masculine	9
	10	Schornstein (chimney)	2	yes	masculine	3
	11	Schildkröte (turtle)	3	yes	feminine	31
	12	Schlauch (hose)	1	no	masculine	2
	13	Schloss (padlock)	1	no	neuter	–
	14	Schlitten (sledge)	2	no	masculine	5

(*continued*)

Appendix. (*Continued*)

	Item	Syllable	Compound	Gender	Frequency[1]
15	Schleife (bow)	2	no	feminine	5
16	Schlüssel (key)	2	no	masculine	19
17	Schlange (snake)	2	no	feminine	2
18	Schlittschuhe (skates)	3	yes	feminine	–
19	Schnee (snow)	1	no	masculine	29
20	Schnecke (snail)	2	no	feminine	–
21	Schnabel (beak)	2	no	masculine	9
22	Schneemann (snowman)	2	yes	masculine	–

[1]CELEX (Baayen, Pipenbrock, & Gulikers, 1995), spoken language per million according to corpus of Mannheim.
[2]No numerical value.