School-Aged Children's Production of /s/ and /r/ Consonant Clusters

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Key Words

Consonant cluster • Speech development, typical • Speech acquisition, typical

Abstract

Objective: To describe the acquisition of /s/ and /r/ word-initial consonant clusters across 2 elicitation modalities. **Patients and Methods:** Seventy-four typically developing children aged 5–12 years produced 2- and 3-element /s/ and /r/ consonant clusters in word-initial position. Stimuli were presented pictorially and as written words in separate trials. **Results:** Overall, 94.5% of the consonant clusters were produced correctly. Two-element /r/ clusters were 94.0% correct, 2-element /s/ clusters were 96.8% correct, and 3-element clusters were 92.0% correct. The age of acquisition was typically younger than established by previous researchers. The characteristic non-adult production of /s/ consonant clusters was the substitution of /s/ with interdental or lateral phonemes, and of /r/ consonant clusters the substitution of /r/ with [w]. The last consonant clusters to be mastered were: /θr/ (thr), /str/, /spr/ and /skr/. There were no significant differences in error rates across the modalities; although younger children required significantly more prompting when naming written words. **Conclusion:** Primary-school-aged children characteristically produced /s/ and /r/ consonant clusters correctly. The accuracy of production was not influenced by the elicitation modality. Elicitation using pictures compared with written words was more efficient for 5- to 8-year-olds. Both elicitation modes were equally efficient for 9- to 12-year-olds.

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Introduction

Understanding typical speech acquisition is important for benchmarking the difference between typical and atypical speech development, and for the identification of appropriate intervention targets in children with speech impairment. The majority of information that is known about children's speech acquisition concerns the acquisition of consonants [1, 2]. However, even within the large corpus of data on singleton consonants wide discrepancies in the age of acquisition are found, particularly for /s, z/ and /r/. For example, the reported age of acquisition for /s/ varies from 3 [3, 4] to 7 years of age [5]. Similarly, the range for the age of acquisition of /r/ extends from 3 [4] to 6 years of age [3]. Possible reasons for the discrepancy relate to (a) the differing complexity of targeted words, (b) the definition of acquisition and (c) the elicitation modalities employed [2].

Complex Targets: Consonant Clusters

In comparison with the number of studies of the acquisition of singleton consonants, relatively few studies of English-speaking children have considered the acquisition of consonant clusters, despite the fact that one third of English monosyllables begin with a consonant cluster (e.g. /pr/ and /str/) [6]. The acquisition of consonant clusters is one of the longest lasting aspects of speech acquisition in typically developing children [7]. Children as young as 2 years of age can produce some consonant clusters correctly [8, 9]. For example, the children in one study [9] aged between 2;0 (i.e. 2 years and 0 months) and

3;4 years had an average of 29.5% consonant clusters correct in conversational speech with a wide range of variability (range = 0.0–79.1%) [10]. During the preschool and school years children continue to develop skills in the production of consonant clusters. According to Smit [11], the latest consonant clusters to be acquired are 2-element /r/ and /s/ clusters and 3-element /s/ clusters. Some researchers, including Waring et al. [12], suggest that a correct production of consonant clusters is achieved by 96.6% of 6-year-olds and 98.3% of 7-year-olds. However, according to others, including Smit et al. [1, 11], 9-year-olds are still mastering consonant clusters such as /str/ and /skr/ which were produced correctly by fewer than 90% of the children studied. As with singleton consonant acquisition, there are discrepancies in the age of acquisition within the published studies, necessitating a larger corpus of data from additional studies to inform speech-language pathology (SLP) practice. Consequently, this study aims to explore the age of mastery of /s/ and /r/ consonant cluster production in school-aged children.

A further reason for examining the typical acquisition of consonant clusters is that almost all children with speech impairment are reported to have difficulty producing consonant clusters [13–15]. Difficulties producing consonant clusters in very young children have been noted for their potential predictive value in the identification of speech impairment [7, 16]. Difficulty producing consonant clusters has been found to contribute to high levels of unintelligibility in children with speech impairment [17], particularly as a result of cluster reduction. Consonant clusters are frequently identified as targets for SLP intervention [13–15]. Indeed, Gierut and Champion [13, 14] suggest that, due to their complexity, consonant clusters provide a facilitative environment for the generalization of gains to singleton contexts. Remediation of consonant cluster production often results in generalizable gains to the child's broader phonological system, particularly to non-targeted singleton consonants [18]. Consequently, speech-language pathologists need comprehensive information regarding the typical acquisition of consonant clusters to appropriately assess and provide intervention for their clients.

Definition of Acquisition

Over the years, the definition of the acquisition of consonants and consonant clusters has included the correct production by 50, 75, 90 or 100% of the participants across 1, 2 or 3 word positions (i.e. initial, within a word and final) [1, 3–5]. The term 'mastery' is often used when at least 90% of children produce a consonant or consonant

cluster correctly [3]. To explicate the effect of these different definitions, researchers such as Sander [19] and Smit et al. [1] have provided graphical representations of the age of acquisition for each consonant, demonstrating variability and differing slopes in the trajectory of acquisition. To date, most studies have only documented means which preclude knowledge of the impact of outlying individual scores. Consequently, this study aims to graphically present individualized data as well as to provide the percentage of children who accurately produce each consonant cluster.

Elicitation Modalities

The chosen modality for eliciting children's speech may affect the reported age of acquisition. Additionally, knowledge of the most efficient method of eliciting children's speech production is also of interest to streamline the identification of children requiring SLP services. Differences in the occurrence of errors and the presence of phonological processes have been found between various elicitation techniques including the production of single words and connected speech [20, 21], and between imitated and spontaneous elicitation techniques [22, 23]. To date no one has studied differences between pictorial and written stimuli for the elicitation of speech since most studies include younger children who are unable to read. A pictorial representation of the required word may be less efficient than an orthographic representation for older children due to the sometimes ambiguous target of pictorial stimuli (e.g., if a picture of three green circles is shown, is the target *circle*, *green* or *three*?). However, if an orthographic representation is given, it is possible that the child may produce more accurate productions because it has been provided with additional cues regarding the required sounds (e.g., if the target is *three*, does the visual stimulus of the letters 'th' increase the level of accuracy of production of the /θ/ sound?). There is also evidence that the ability to read and spell words containing consonant clusters may pose particular difficulty for children, especially those with speech impairment [24, 25]. For example, Treiman [25] found that CCV nonsense syllables were more difficult for beginning readers to decode than CVC syllables. Treiman also found that young children were less able to recognize spoken or printed target consonants when they were the first phoneme of a cluster than when they were a singleton.

Considering that complex targets, the definition of acquisition and the elicitation modality can impact the stated age of acquisition, the aim of the present investigation was to examine typical primary-school-aged children's

Table 1. Participant characteristics and percent of consonant clusters correct

Group	Number	Average age years;months	Number of males	Number of females	Percent of imitated responses	Percent of consonant clusters correct	Percent of 2-element /r/ clusters correct	Percent of 2-element /s/ clusters correct	Percent of 3-element /s/ clusters correct
5–6 years	19	6;2	7	12	16.1	92.4	89.7	97.9	89.0
7–8 years	16	7;8	7	9	5.8	89.7	86.7	95.1	86.9
9–10 years	23	9;9	10	13	1.5	96.5	99.2	95.8	93.3
11–12 years	16	11;6	8	8	0.9	98.8	98.8	98.7	98.8
Total	74	8;8	32	42	2.4	94.5	94.0	96.8	92.0

mastery of /s/ and /r/ consonant clusters and to determine the effect of a written versus a pictorial presentation of stimuli.

Method

Participants

Seventy-four typically developing children aged 5–12 years were participants in this research (table 1). There were 32 males and 42 females. Participants were recruited from a total of 3 schools in New South Wales, Australia. According to their teacher/parent, each of the participants was reported to have no speech difficulties (e.g. they had not received SLP services), no hearing difficulties nor any other disabilities. The research took place towards the end of the school year, so even the youngest children had been learning to read for almost a year. All children were reported as being typical for their age on cognitive tasks including reading.

Procedure

After parental consent was received, participants' production of consonant clusters was assessed for each child individually in a quiet room in their school. Forty words were selected from the single word sampling task outlined in McLeod et al. [21]. The selected words were designed to assess each 2-element /r/ cluster and each 2- and 3-element /s/ cluster in English, using words that commonly occurred in children's speech [26]. There were 2 different words to represent each consonant cluster; for example, /br/ was represented by *bread* and *brush*. The words were ordered so that children did not produce words containing the same consonant clusters concurrently. The stimuli were presented individually via a PowerPoint presentation on a laptop computer. Half of the words (i.e. 1 complete set of consonant clusters) were presented as a colour photograph (the same as used by McLeod et al. [21]), and the other half as written words; the order of presentation was counterbalanced so that order effects were reduced. That is, there were 4 groups of children in each age group: those who received (a) pictures for list 1, then words for list 2; (b) words for list 1, then pictures for list 2; (c) words for list 2, then pictures for list 1, and (d) pictures for list 2, then words for list 1.

The children were asked to produce each word spontaneously. If they were unable to produce the word, then they were provided

with an elicitation cue (e.g., to elicit the word *green*, they were asked 'What colour is the grass?'). The word was imitated by the child only if other elicitation cues were unsuccessful. There was no time limit on children's responses. Once the child responded, the experimenter pressed the arrow on the keyboard to move to the next stimulus. The children's productions of consonant clusters were transcribed online using a score form containing possible phonetic transcriptions, as well as space to write other productions. The correct production of consonant clusters was defined as standard Australian English adult production. Residual errors including interdental and lateral lisps, [w] for /r/ and [f] for /θ/ were counted as non-adult productions. The children's productions were also recorded using a JNC USB-350 digital voice recorder. These recordings were checked to determine the accuracy of the transcription as well as for reliability measures. Eleven participants were randomly selected, and an experienced speech-language pathologist (S. McLeod) retranscribed the children's consonant cluster productions using audio recordings. The point-by-point reliability was calculated for 984 consonants produced within the consonant clusters by the 11 participants. The inter-judge reliability was 97.7%.

Results

Percentage of Consonant Clusters Correct

The overall percentage of consonant clusters correct was 94.5 for the children aged 5–12 years. More children consistently produced clusters correctly as the age of the children increased (fig. 1). Thirty-nine of the 74 children produced 100% of the consonant clusters correctly. The youngest child who produced all consonants correctly was a female aged 5;10 years. A further 25 children produced at least 90% of the consonant clusters correctly. There were 10 children who produced fewer than 90% of consonant clusters correctly (fig. 1). For example, 1 female who was 112 months (9;4 years) old, scored 40% of consonant clusters correct since she produced an interdental lisp for all /s/ clusters.

Fig. 1. Percentage of consonant clusters correct compared with the age of individual participants (n = 74).

Table 2. Percentage of individual consonant clusters correct by age group

Group	2-element /r/ clusters								2-element /s/ clusters							3-element /s/ clusters				
	pr	br	tr	dr	kr	gr	fr	θr	sp	st	sk	sm	sn	sl	sw	spl	spr	skw	skr	str
5–6 years	85.0	92.5	100.0	90.0	97.5	97.5	85.0	70.0	97.5	100.0	95.0	100.0	97.5	95.0	100.0	87.5	85.0	90.0	92.5	90.0
7–8 years	87.5	90.6	90.6	84.4	93.8	84.4	90.6	71.9	96.9	93.8	96.9	93.8	96.9	93.8	93.8	96.9	84.4	93.8	78.1	81.3
9–10 years	100.0	100.0	100.0	100.0	100.0	100.0	100.0	93.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	93.8	95.8	93.8	91.7	91.7
11–12 years	100.0	100.0	100.0	100.0	100.0	100.0	100.0	90.6	100.0	100.0	96.9	100.0	100.0	96.9	96.9	100.0	96.9	100.0	100.0	96.9
Total	93.4	96.1	98.0	94.1	98.0	96.1	94.1	82.2	97.4	97.4	96.1	97.4	97.4	95.4	96.7	94.1	90.8	94.1	90.8	90.1

Production of Individual Consonant Clusters

Overall, 2-element /s/ clusters were more likely to be produced correctly (96.8%), followed by 2-element /r/ clusters (94.0%), then 3-element /s/ clusters (92.0%) (table 1). The consonant clusters that were produced correctly the most often were /tr/ and /kr/ (produced correctly 98.0% of the time by all the participants) (table 2). This was closely followed by /sp, st, sm/ and /sn/, produced correctly 97.4% of the time by all the participants. The consonant cluster that was least likely to be produced correctly was /θr/, being produced correctly only 82.2% of the time by all the participants. Three-element consonant clusters containing /r/ (/spr, skr/ and /str/) were the next least likely to be produced correctly.

Some consonant clusters were produced correctly by fewer than 90% of the children aged 5–8 years (table 2). The most difficult consonant clusters for the 5- to 6-year-olds were /pr, fr, θr, spl/ and /spr/, and the most difficult consonant clusters for the 7- to 8-year-olds were /pr, dr, gr, θr, spr, skr/ and /str/. For the majority of the non-adult

productions of 2-element /s/ consonant clusters, the second element was correct and the /s/ realized either as an interdental or lateral lisp. In contrast, for the majority of non-adult productions of 2-element /r/ clusters, the first element was correct and the /r/ realized as [w]. The exception to this was the 2-element /r/ consonant cluster /θr/, where all but 1 non-adult production of this consonant cluster was of the form [fr]. Production of [f] for /θ/ has been indicated as a dialectal variation of Australian English [27], so this may have influenced the realization of this consonant cluster. The children's realizations of the 3-element /s/ clusters were similar to their non-adult realizations of 2-element /s/ clusters, demonstrating interdentalization and substitution of /r/ with [w], as Smit's data have shown [11]. The children reduced 3-element consonant clusters to 2 elements 6 times, and this only occurred in children aged 5–8 years. In each case the third element was deleted; thus, /spl/ → [sp], /skr/ → [sk], /spr/ → [sp], and /str/ → [st].

Fig. 2. Percent occurrence of (a) error responses and (b) imitated responses when stimuli were elicited by pictures or written words presented as an effect of the age of the children.

Comparison between Pictorial and Written Elicitation Modalities

Each child received pictorial stimuli for one word depicting each consonant cluster ($n = 20$) and written stimuli for another word depicting each consonant cluster ($n = 20$). Comparisons were made between the impact of the mode of stimuli presentation on (a) whether the consonant clusters were produced correctly or not, and (b) whether the words were produced spontaneously or were imitated. Figure 2 provides a summary of the data. The most notable feature was the higher rate of imitations for written stimuli presented to younger children. In order to statistically compare the impact of the elicitation modality, 2 separate item analyses were undertaken, using percent occurrence as the dependent variable. First, error rate (accuracy) data were analysed. An ANOVA with age as a non-repeated measure with 4 levels (5–6 vs. 7–8 vs. 9–10 vs. 11–12 years) $\times$ modality as a repeated measure with 2 levels (words vs. pictures) revealed a main effect of age ($F_{3, 156} = 13.50$; $p = 0.0001$) and no other significant effects. Post hoc comparisons (Tukey's test) revealed significant differences for all comparisons with 2 exceptions. Averaged across modality there were no significant differences in the overall error rates exhibited by 5- to 6-year-olds versus 7- to 8-year-olds, or by 9- to 10-year-olds versus 11- to 12-year-olds. Second, the data were analysed for imitation rates. An ANOVA with age as a non-repeated measure with the same 4 levels and modality as a repeated measure with the same 2 levels revealed a main effect of age ($F_{3, 156} = 23.79$; $p = 0.0001$), a main effect of modality ($F_{1, 156} = 24.76$; $p = 0.0001$) and a significant interaction ($F_{3, 156} = 26.20$; $p = 0.0001$). Follow-up paired t

tests (Bonferroni's corrected) revealed that the only statistically significant differences between written versus pictorial stimuli were in the 5- to 6-year-old children and the 7- to 8-year-old children. These younger children required more prompting when presented with written stimuli.

Discussion

Primary-school-aged children typically produced /s/ and /r/ consonant clusters correctly (mean = 94.5%). As the children became older, more produced all of the consonant clusters correctly. The age of acquisition was typically younger than found by Smit et al. [1], with 14 of the 20 consonant clusters produced at mastery level (>90%) by children aged 5–6 years in the present study. There are a number of differences between the current study and Smit et al. [1] that may explain the earlier acquisition, including sample sizes, stimuli, elicitation modalities and the 2 decades between the data collection for the studies.

There was a statistically significant difference between the error rates produced by 5- to 8-year-olds versus 9- to 12-year-olds; however, this was not as a result of the elicitation modality. There was no significant difference between pictorial and written stimuli with respect to the number of consonant clusters produced correctly. However, for the 5- to 8-year-old children there was a significant difference between the elicitation modalities for the number of imitation prompts required to achieve accuracy in their production of consonant clusters. Thus, the

use of pictorial stimuli was supported as being more efficient for younger children, due to the fact that, when looking at pictorial stimuli, they required fewer imitation prompts. This finding, coupled with the work of Treiman [25], suggests that young children had difficulty reading words that commence with consonant clusters.

A limitation of the study was that there were slightly disproportionate numbers of males and females and children in each age group. This was an artefact of the community-based sampling procedure and could be addressed in future studies. Future studies examining children's production of consonant clusters could also include polysyllabic words containing consonant clusters since they would increase the complexity of the target and may lead to fewer children achieving mastery production. Polysyllabic words also allow for an examination of consonant cluster production in stressed versus unstressed syllables. A recent study by Arciuli and McLeod [28] has revealed

that /st/ cluster production is more accurate in the stressed syllable of both trochaic (strong-weak) and iambic (weak-strong) contexts. The results of the present study contribute to our understanding of children's acquisition of consonant clusters. Children aged 5–8 years continue to have some difficulty producing a few 2- and 3-element consonant clusters, particularly if they contain /r/; however, between the age of 9 and 12 years children have achieved mastery of consonant clusters. Written versus pictorial elicitation stimuli make no difference to the accuracy of production; however, pictorial stimuli are more efficient for younger children since they require more imitative prompts when faced with written stimuli.

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