Author: D. G. H. James, J. van Doorn, S. McLeod and A. Easterman
Author Address: smcleod@csu.edu.au; -
Title: Patterns of consonant deletion in typically developing children aged 3 to 7 years
Year: 2008
Journal: International Journal of Speech-Language Pathology
Volume: 10
Issue: 3
Pages: pp179-192
ISSN: 1754-9507
URL: http://dx.doi.org/10.1080/17549500701849789
DOI: Keywords: polysyllabic words
assessment
typical development
speech
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Patterns of consonant deletion in typically developing children aged 3 to 7 years

DEBORAH G. H. JAMES[1, 2], JAN VAN DOORN[2,3], SHARYNNE MCLEOD,[4] ADRIAN ESTERMAN[5]

[1]*Flinders University, Australia;* [2]*University of Sydney, Australia;* [3]*Umeå University, Sweden,* [4]*Charles Sturt University, Australia,* [5]*University of South Australia, Australia*

Correspondence: Dr Debbie James, Senior Lecturer in Speech Pathology, Department of Speech Pathology and Audiology, Flinders University, GPO Box 2100, Adelaide 5001, South Australia. Tel: +61 8 8204 5937. Fax: +61 8 8204 5935. Email: Debbie.james@flinders.edu.au

Running head: Typical patterns of consonant deletion

Abstract

Children with and without speech, language and/or literacy impairment, delete consonants when they name pictures to elicit single words. Consonant deletion seems to be more frequent in long words (words of three or more syllables) than in short words (words of one or two syllables). However, it may be missed in long words because they are not routinely assessed and, even if they are, there is little normative data about them. The study aims were (1) to determine if a relationship exists between consonant deletion and the number of syllables in words, (2) delimit variation in the numbers of children using it, its frequency of occurrence and the words it affects and (3) to discuss the application of these data to clinical practice. The participants were 283 typically developing children, aged 3;0 to 7;11 years, speaking Australian English with proven normal language, cognition and hearing. They named pictures, yielding 166 selected words that were varied for syllable number, stress and shape and repeatedly sampled all consonants and vowels of Australian English. Almost all participants (95%) used consonant deletion. Whilst a relationship existed between consonant deletion frequency and the number of syllables in words, the syllable effect was interpreted as a proxy of an interaction of segmental and prosodic features that included two or more syllables, sonorant sounds, non-final weak syllables, within-word consonant sequences and/or anterior-posterior articulatory movements. Clinically, two or three deletions of consonants across the affected words may indicate typical behaviour for children up to the age of 7;11 years but variations outside these tolerances may mark impairment. These results are further evidence to include long words in routine speech assessment.

Key words: polysyllabic words; assessment; typical development; speech

Background

Consonant deletion that occurs in single words, elicited from picture naming, is one marker of impairment in paediatric speech, language and literacy (Leitão, Hogben, & Fletcher, 1997). It also characterises normal speech during its acquisition (Haelsig & Madison, 1986). In this paper, the term consonant deletion encompasses any deletion of consonants, be they singletons, constituents of clusters or from consonant sequences that form when syllable edges meet (*oc.topus*). Consonant deletion also subsumes relevant phonological processes such as initial and final consonant deletion and cluster reduction.

Some types of consonant deletion occur in both typically and atypically developing speech. Deletions of word-final and intervocalic consonants as well as consonants from initial clusters and within-word consonant sequences occur in typically and atypically developing speech (Dodd, 1995; Haelsig & Madison, 1986; Preisser, Hodson, & Paden, 1988). In contrast, initial consonant deletion usually occurs in atypically developing speech only (Dodd, 1995). Regardless of the type of consonant deletion, the frequency with which typically developing children use it is one source of information speech pathologists use to judge children's speech status. That is, if the occurrence of consonant deletion for an individual exceeds the tolerances for typically developing peers, then that individual may be identified with an impairment. Thus, a consideration in clinical decision-making is determining the appropriate frequency range of consonant deletion for a designated age because of the variability in consonant deletion in singleton and cluster contexts, as displayed in Table 1. Table 1 contains a summary of studies of typically developing children reporting consonant deletion. Variability is conspicuous in this summary for both the frequency of consonant deletion and the percentages of children within studies who demonstrate it.

INSERT Table 1 here

Some of this variability is attributed to the numbers of long words (words or three or more syllables) sampled across the studies. This is so because the occurrence of consonant deletion and the numbers of children demonstrating it were higher in studies where five or more long words were sampled, (Haelsig & Madison, 1986; James, 2001a; Vihman & Greenlee, 1987) than in studies where four or fewer long words were sampled (Dodd, Holm, Hua, & Crosbie, 2003; Hodson & Paden, 1981; Khan & Lewis, 1986; Roberts, Burchinal, & Footo, 1990) (see James, 2006). More generally, mismatches increased as the numbers of syllables increased, observed in individual consonant accuracy (Ingram, Christensen, Veach, & Webster, 1980) and in the composite scores of percentage of phonemes correct (Echols & Newport, 1992), percentages of consonants correct (James, van Doorn, & McLeod, 2002; Vance, Stackhouse, & Wells, 2005) and percentage of vowels correct (James, van Doorn, & McLeod, 2001).

Other considerations in clinical decision-making are that a) some aspects of speech development are only revealed in long words (James, 2006) and b) some impairment is only revealed, or appears more severe, when long words are used in assessment and, conversely, is concealed or underestimated when short words (words of one or two syllables) are used (James, 2006). This effect is present within and across four paradigms of speech testing; conversational speech, picture naming, real word repetition and non-word repetition for typically developing children and those with speech, language and literacy impairment. For example, younger typically developing children were indistinguishable from older typically developing children on short words when naming pictures, repeating real words and repeating nonwords but differences emerged on long words for all three paradigms (Vance et al., 2005). Children with speech impairment performed less well on long words than on short words in conversational speech (Hargrove, 1982), when naming pictures (James, 2001b; Klein & Spector, 1985; Pollock, 1991) and repeating real words (Bernhardt & Major, 2005).

Similarly, children with language and speech impairment performed less well on long words than short words when naming pictures (Constable, Stackhouse, & Wells, 1997) and repeating non words (Aguilar-Mediavilla, Sanz-Torrent, & Serra-Raventos, 2002; Dollaghan & Campbell, 1998l; Gathercole & Baddeley, 1990; James, van Steenbrugge, & Chiveralls, 1994). Likewise, children with reading impairment were indistinguishable from their typically developing peers when naming pictures of short words but differences emerged when naming pictures of long words. (Katz, 1986). Some of the mismatches the children with reading impairment used were deletions of consonants.

Performance differences between long and short words are present across different testing paradigms for atypically developing children. Lewis and colleagues (Lewis & Freebairn, 1992; Lewis, Freebairn, & Taylor, 2000) found that speech impairment in participants, aged 9 to 23 years, was only apparent when repeating long words and not on picture naming tasks dominated by short words whereas it was apparent in 5-year-olds in short words. In a longitudinal study, Bishop and colleagues (Bishop & Adams, 1990; Bishop & Edmundson, 1987; Snowling, Adams, Bishop, & Stothard, 2001; Snowling, Bishop, & Stothard, 2000; Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998) examined the speech, language and literacy of 87 children with LI, identified by four years of age and monitored over a 14-year time span. It was evident in their findings that speech measured on a picture naming test dominated with short words in the first two studies when the participants were 4;0, 4;6, 5;6 and 8;6 years-of-age (Bishop & Adams, 1990; Bishop & Edmundson, 1987) was not as predictive of outcomes as a repetition test dominated with long nonwords used in the second two studies (Snowling et al., 2000; Stothard et al., 1998) when the participants were 15 years-of-age. Dodd and colleagues (Dodd, Russell, & Oerlemans, 1993; Dodd, Sprainger, & Oerlemans, 1989; Gillon & Dodd, 1993, 1994) reported that participants with confirmed literacy impairment significantly under-performed compared with their typically developing peers on a repetition task of long words, despite the majority having speech skills that were reported as normal speech at the time of testing. More particularly, Leitão et al. (1997) reported that children with language impairment had normal speech on a picture-naming test dominated by short words but on a repetition task of long words had significantly more consonant deletion than their typically developing peers.

Children acquiring speech, either typically or atypically, use consonant deletion. Further, consonant deletion frequency may be positively related to the number of syllables in words such that some consonant deletion may only occur in long words. The significance of this notion is highlighted when considering the following. If long words contribute unique information about speech status, then testing that relies mostly on short words may not fully delimit speech skills and this, in turn, may confound examining relationships between speech and other outcomes. Evidence for this confounding influence can be found within the findings regarding the relationship between speech and literacy. For example, in studies where speech testing included five or fewer long words, either no relationship or a weak relationship existed between speech and literacy (Bishop & Adams, 1990; Catts, 1993) whereas a relationship was found in studies that included nine or more long words, (Elbro, Borstrøm, & Petersen, 1998; Larrivee & Catts, 1999; Leitão et al., 1997; Lewis & Freebairn, 1992; Lewis et al., 2000; Lewis, Freebairn, & Taylor, 2002; Stothard et al., 1998). Also within some of these same studies, when results from tests containing fewer than five long words were correlated with the results of reading tests no relationship was evident, but it was evident when the speech tests containing five or more long words were used (Larrivee & Catts, 1999; Leitão et al., 1997; Lewis & Freebairn, 1992; Lewis et al., 2000; Lewis et al., 2002). These findings can be interpreted to imply that long words provide unique information about speech.

Thus, the aims of this study were to determine if a relationship exists between consonant deletion frequency and the number of syllables in words in the speech of typically developing children as well as to define normal variation of consonant deletion in words of differing syllable numbers. Three aspects of normal variation are examined; the numbers of children using consonant deletion, the frequency with which consonant deletion is used, and the words affected by consonant deletion. The significance of this study lies in the notion that if consonant deletion in long words marks impairment and consonant deletion is still present in typically developing children's speech over the span of 3 to 7 years, then it is important to differentiate deviance from development. If the patterns of consonant deletion in long words observed in impairment are also characteristic of typical development, it will be important to define and delineate typical behaviour in long words before determining the clinical significance of error patterns in impairment. The three hypotheses of this study are that consonant deletion increases as the number of syllables in words increases, decreases as age increases, and that age and syllable numbers interact such that in older children, consonant deletion only occurs in long words.

Method

This study is part of a larger study describing the speech of typically developing children, aged 3 to 7 years, reported elsewhere (James, 2006; James et al., 2001; James et al., 2002).

Participants

A total of 283 South Australian children, aged 3;0 to 7;11 years (see Table 2), participated in the study meeting the inclusion criteria of proven normal hearing, language and cognitive skills. The participants aged 4 to 7 years were randomly sampled from all preschools and schools in South Australia, using a two-staged, proportional stratified, cluster sampling procedure (Bowling, 1997). This sample matched the South Australian demography for rural, urban and suburban location and socio-economic status, based on 1991 census data (Australian Bureau of Statistics, 1993). Three-year-olds were non-randomly sampled because there was no central register, unlike the older group where the entire population could be accessed through the school system. Cluster sampling has a design effect consequent to hierarchically arranged data. People in clusters are more alike relative to people within another cluster, and this design effect can exaggerate between-group differences and lead to Type 1 errors (Keeves & Sellin, 1997). Thus cluster sampling effects were removed.

INSERT table 2 about here

Speech stimuli

Speech was assessed using the speech test, *Assessment of Children's Articulation and Phonology* (ACAP) (James, unpublished). This test was developed for the larger study and its construction has been described elsewhere (James, 2001b; James, 2006). The test was developed from a prototype that was pilot tested and subjected to an item analysis. The final 166 mono-, di- and polysyllabic words[1] included in the test met the inclusion criteria for content validity, item difficulty and item discrimination and sampled all vowels and consonants of Australian English. All vowels were sampled in syllables with primary and secondary stress and schwas were sampled in initial, within-word and final syllables. In addition, all consonants were sampled in the initial and final positions of syllables within words and at their edges in words where syllables were varied for number, stress and shape, reflecting the tenets of contemporary phonology. The test was loaded with consonants prone to error during acquisition, such as the fricatives and liquids (Ingram et al., 1980). In addition, the test involved the repetition of 16 of the test words to check stability of word production.

[1] From hereon, the terms long and short words are used when collective terms are required and the terms mono-, di- and polysyllabic words are used when more specificity is required. In this paper, the term polysyllabic words denotes words of three or more syllables.

Further details of the words included in the test along with the sampled segments can be viewed in James (2001b, 2006). The total opportunities for sampling words and consonants in ACAP for this study varied for different age groups because participants aged four years and older completed the full form of the test whereas the 3-year-olds completed the screening form (82 words and 11 words for stability). The stability subtest was administered twice to the 3-, 4- and 5-year-olds attending kindergarten and once to all other participants.

Procedure

After parents completed a questionnaire about the child's health and developmental progress, the participants were individually assessed. Spontaneous picture naming was sought and planned prompting was used as needed.

Data Analysis

Words were transcribed according to a pre-determined protocol. Broad transcription was used except when phoneme production was judged outside normal tolerances of pronunciation, according to the second edition of *Macquarie Dictionary* (Delbridge, Bernard, Blair, Peters, & Butler, 1991), a dictionary of Australian English. In these cases, narrow transcription was used. For example, dentalisation or lateralisation diacritics were used when /s/ or /z/ were judged as dentalised or lateralised. If final consonants were judged as unreleased or replaced with a glottal stop, these notations were made. The length diacritic was added when vowels were judged as too long for their context.

Data were entered into the PROPH+ component of *Computerized Profiling (version 8OT)* (Long & Fey, 1996). Words were then coded for consonant deletion according to the following protocols. Consonant deletion was noted whenever consonants were absent from the transcription of words and this pronunciation varied from that stated in the second edition of *Macquarie Dictionary* (Delbridge et al., 1991). The reference pronunciations for words such as *pumpkin, sandwich* and *husband* were [pʌmpkən, sænwɪtʃ] and [hʌzbənd] respectively. Vocalisation of syllable-final /l/ in words such *bulldozer* said as [bʊdoʊzə] and *girl* said as [geʊ] was judged as normal South Australian English (Clark & Yallop, 1995; James, 2001a) and therefore did not count as deletion.

Consonants deleted from sequences were assigned to syllables using the principles described by Grunwell (1982; 1985). For example, when computer was said as [kəpjutə], the deleted /m/ was recorded as deletion of a within-word, syllable-final consonant whereas when *ambulance* was said as [æmbələns] rather than [æmbjələns] the deleted /j/ was recorded as within-word syllable-initial cluster reduction. No distinction was made between complete or partial cluster reduction. When complete cluster deletion occurred, the number of deletions was the number of consonants in the cluster. This convention also held for consonant sequences, that is, sequences that form when consonants abut syllable edges, such as /mbj/ and /pt/ in *ambulance* and *helicopter* respectively. Substituted consonants were not counted as consonant deletion because the consonant slot was considered represented in the output. However, if the number of consonants in a sequence was not preserved, then consonant deletion was counted. For example, when *pumpkin* was realised as [pʌŋkkən], consonant deletion was not counted because all segments in the sequence of /mpk/ were assumed to be represented, albeit incorrectly. However, when *pumpkin* was said as [pʌŋkən], consonant deletion was counted. A *post hoc* decision was taken to exclude one other deletion. The deletion of /t/ from *left* was usually excluded because its prompting usually resulted in the two-word phrase, *left foot,* realised as [lefut], rather than the intended single word *left*.

Reliability

Transcription reliability was 88% to 95% (See James (2006) for further details). An experienced speech pathologist coded 10% of the data for consonant deletion with 94% agreement.

Results

Almost all participants (95%) used consonant deletion in about half the words 1,161 times. Consonant deletion occurred 63 times in 26% of the monosyllabic words (MSWs), 549 times in 46% of disyllabic words (DSWs) and 543 times in 82% of the polysyllabic (PSWs). Individual use varied from zero to 39 times, with a mode of 3. The distribution of scores was positively skewed, confirmed by the Shapiro-Wilks test of normality.

Number of participants using consonant deletion

Almost all participants used consonant deletion (94%), ranging from 79% of the cohort using it in PSWs to 17% of the cohort using it in MSWs. This decreased with increasing age within each word category. Six times the percentage of 7-year-olds used consonant deletion in DSWs and PSWs compared with MSWs, while only about twice the percentage of 3-year-olds used consonant deletion in DSWs and PSWs compared with MSWs, as displayed in Table 3.

INSERT table 3 about here

The frequency of use of consonant deletion

Frequency of consonant deletion use was converted to a percentage score using the total number of words each participant said as the denominator. The frequency of consonant deletion use varied with age and the number of syllables, as displayed in Table 3 and Figure 1.

INSERT Fig 1 about here

There was an interaction in consonant deletion scores between age and the numbers of syllables in words, apparent in Figure 1 and confirmed with a 2-way ANOVA with repeated measures. In the latter, the coefficient for the interaction term was highly significant (Wilks' Lamda =0.92; $F_{98,554}$= 3.01; p=0.003). Since the distribution of consonant deletion scores was positively skewed, it was first transformed using a natural logarithm (ln(0.001 + CD score) before entering into the ANOVA.

Age

Consonant deletion medians decreased with increasing age, with age effects confirmed by the Kruskal-Wallis test for MSWs ($\chi^{2=}$ 14.07 df =4; p<0.05), DSWs ($\chi^{2=}$ 39.26; df =4; p<0.001) and PSWs, ($\chi^{2=}$ 48.60; df =4; p<0.001). This decrease was linear, confirmed by the NP trend test (Cuzick, 1985) and evident for MSWs (Z=2.56; p<0.05), DSWs (Z=2.50; p<0.001) and PSWs (Z=3.71; p<0.001). Planned post hoc comparisons between age groups were made using the Mann-Whitney U-test with a modified Bonferroni correction (Jaccard & Wan, 1996). The comparisons indicated more differences existed within age groups for DSWs and PSWs than for MSWs, summarised in Table 4. The clustering effect was assessed using the statistical package STATA (StataCorp, 2003). The analysis for age was repeated using regression models allowing for clustering, with no change to the overall age effect.

INSERT table 4 about here

Syllables

Consonant deletion medians increased as the numbers of syllables in words increased with a syllable number effect apparent in Figure 1 and confirmed by the Friedman test ($\chi^{2=}$ 287.10; df=2; p<0.001). Differences existed between MSWs and DSWs, and MSWs and PSWs overall as well as for each age group, tested using a modified Bonferroni adjustment. There were no differences between DSWs and PSWs.

Contexts of consonant deletion

Consonant deletion frequency was not only influenced by the number of syllables in words but also by the phonotactics of words and syllable stress. To determine the relative impact of these contexts on the consonant deletion frequency, consonant deletion was converted to a percentage using the total number of consonants in the test words as the denominator.

Phonotactics

Consonants were deleted from intervocalic, syllable-initial and syllable-final positions within words and at their edges, affecting singletons and sequences, as displayed in Tables 5 and 6. Intervocalic consonants and consonants from sequences were deleted more frequently than singleton syllable-initial and syllable-final consonants. These trends reflect the observation that most participants (91%) used cluster reduction. By contrast, less than half the participants used consonant sequence reduction and intervocalic consonant deletion, as displayed in Table 5. Very few participants used singleton consonant deletion, evident in Table 6.

INSERT table 5 about here

INSERT table 6 about here

Consonant sequence reduction

Consonant sequence reduction, occurred in DSWs and PSWs and was affected by age as apparent in Table 5 and confirmed by the Kruskal-Wallis test ($\chi^{2=}$ 35.38; df =4; p<0.001).

Cluster reduction

A two-way ANOVA with repeated measures found no statistically significant interaction effect between age and number of syllables for cluster reduction (Wilk's Lambda=0.92; $F_{98,554}$=1.70; p=0.095) after first undertaking a natural logarithm transformation of cluster reduction score.

Cluster reduction medians decreased with increasing age, apparent in Table 5 and confirmed by the Kruskal-Wallis test. The effect only existed for DSWs (χ^{2}= 16.24; df =4; p=0.003). Cluster reduction medians increased as the numbers of syllable in words increased with a syllable number effect confirmed by the Friedman test (χ^{2}= 272.27; df=2; p<0.001). Also, differences existed between MSWs and DSWs, DSWs and PSWs and MSWs and PSWs overall and within each age group, except for the comparison between MSWs and PSWs for 3-year-olds, tested using a modified Bonferroni adjustment. Most cluster reduction occurred in syllable-final consonant clusters in DSWs, then in syllable-initial, word-initial or within-word consonant clusters in PSWs then syllable-initial, word-initial consonant clusters in DSWs.

Intervocalic consonant deletion

Intervocalic consonant reduction was age related, as confirmed by the Kruskal-Wallis test (χ^{2}= 17.76; df =4; p=0.001), despite medians not varying with age.

Syllable stress

About half of all consonant deletion occurred in weak syllables, regardless of phonotactics, as displayed in Figure 2a. The few deletions of syllable-initial consonant mostly occurred in weak syllables. Most consonant deletion occurred in weak syllables in PSW, as displayed in Figure 2b.

INSERT Fig 2 about here

Words affected by consonant deletion

The frequency of consonant deletion for individual words varied from <0.1% to 16% of all consonant deletion for each of the PSWs compared with <0.1% to 26% for each of the DSWs and <0.1% to 1.3% for each of the MSWs. PSWs accounted for 47% of all consonant deletion compared with DSWs accounting for 46% and MSWs accounting for 5%. The affected words are listed in descending order in Table 7 and the rates of consonant deletion for individual words are detailed in the Appendix. Consonant deletion occurred in some words conspicuously more often than in others, with three subgroups of words apparent. The first subgroup consisted of three words, *ambulance, husband* and *pumpkin* whereby each word accounted for 16%, 6.7%, and 26% of all consonant deletion respectively and 48.7% collectively. This contrasted with the second subgroup of 19 words whereby each word accounted for 1% to 4.9% of all consonant deletion and a total of 21.3%. In the remaining subgroup of 57 words, each word accounted for less than 1% of all consonant deletion and a total of 30%.

INSERT Table 7 about here

The most highly ranked MSW, DSW and PSW were *yolk*, *pumpkin* and *ambulance* respectively. All consonant deletion in *yolk* was of the initial /j/ said as [oʊk]. Most consonant deletion in both *pumpkin* and *ambulance* occurred in the within-word consonant sequences. *Pumpkin* was realised in 20 different ways, with 16 involving consonant deletion of the /mpk/ sequence. The most common rendition was [pʌŋkən] and its variants [pʌŋkɪn] and [pʌŋkəm]. Similarly, *ambulance* was realized in 37 different ways with 31 involving consonant deletion. In 30 of these 31 renditions, consonant deletion was in the /mbj/ sequence. The most common renditions were [æmbliəns] and [æmbələns]. For both *pumpkin* and *ambulance,* the percentage of participants using the immature forms of these words decreased with increasing age contemporaneously with increasing percentages of participants using the adult form of these words with increasing age. The pattern of decreasing usage of the immature form of the word with increasing age was not so clear with the word *husband,* the fourth highest ranked word. There was a decrease in the percentage of participants deleting word-final /d/ from 42% to 25% between the 4- and 5-year-olds but then it remained stable at about 25% for the 6- and 7-year-olds. The 3-year-olds did not say this word.

Discussion

This study investigated the patterns of consonant deletion in 283 typically developing children, aged 3;0 to 7;11 years. Almost all participants (95%) used consonant deletion, using it more frequently in PSWs and DSWs than in MSWs. Consonant deletion affected about half the words. However, as most consonant deletion occurred in a few specific DSWs and PSWs, the data need qualitative consideration to determine if the three hypotheses are supported. To do this, the numbers of participants using consonant deletion and the affected words are considered first.

Participants use of Consonant Deletion

Most participants used consonant deletion at low frequencies, indicating it is a common but low frequency behaviour. These observations are consistent with and supportive of the findings of other researchers, summarised in Table 1.

Distribution

The distribution of scores was positively skewed. However, it is not clear if this distribution pattern occurs in other studies because it was not reported. However, if the pattern reported in this study is typical, then it is curious that means and standard deviations are usually reported rather than medians. The use of means from skewed data may lead to an inaccurate conclusion about children's speech status (see James (2001, p. 119) for further discussion of this point).

The words affected by consonant deletion

A conspicuous feature of consonant deletion in this study was its variability across words, with some words accounting for much greater percentages of consonant deletion than others.

This uneven use of consonant deletion implies that it can be triggered by phonological factors additional to the number of syllables in words. These factors include consonant sequences, especially within words, non-final weak syllables, the requirement for an anterior-posterior or posterior-anterior articulation gesture and sonorant sounds. The evidence that these additional factors influence consonant deletion is now described. Firstly, 66% of all consonant deletion affected consonant sequences in word-initial, within-word or word-final positions. These included sequences of consonants that abut syllable boundaries, with or without a cluster. For example, the /mpj/ sequence in *computer* includes a cluster /pj/ but the sequence /dʒt/ in *vegetables* does not. Secondly, 60% of all consonant deletion occurred in sequences within words rather than at their edges. Thirdly, about half the consonant deletion was associated with non-final weak syllables with the deleted consonants either in or abutting them. *Ambulance*, *behind, caterpillar, computer, potato* and *vegetables* were affected in this way, changing to [æmbələns], [əhɪnd], [kæəpɪlə], [kəputə], [əteɪtoʊ] and [vedʒəbʊz] respectively. Fourthly, about half the consonant deletion occurred in consonant sequences that required an anterior-posterior or posterior-anterior articulatory gesture as it occurred in the marked sequences in the following words, *pumpkin, ambulance, music, breakfast, computer* and *vacuum cleaner*. Finally, about half of consonant deletion was associated with the sonorant sounds /m/ and /j/, being the deleted sounds in *pumpkin, ambulance, music, computer* and *vacuum cleaner.* These two sounds as a glide and a nasal respectively are louder, or more sonorous than affricates and stops, consequent to the vocal tract being more open for the former classes of sounds than the latter (Goldsmith, 1990; Roca & Johnson, 1999). These patterns imply that the significant statistical effect for frequency needs qualification and this is discussed in the next section, once the robustness of the above patterns is established through a comparison of these findings with other studies.

The occurrence of consonant deletion in within-word sequences is consistent with and supports other research that finds typically developing children, aged 2 to 7 years, delete consonants from this environment (Gilbert & Johnson, 1978; Ingram, 1989; James, 2001a). More generally, this observation of mismatches in within-word consonant sequences is consistent with and corroborates the findings of Kenney and Prather (1986) for children aged 2 to 5 years. Also, consonant deletion in the /mpk/ consonant sequence in *pumpkin* is consistent with examples James provided (2001a) from another cohort of 50 typically developing Australian children, aged 2 to 7 years.

The observation that about half of the consonant deletion occurred in non-final weak syllables is consistent with the findings of Echols and Newport (1992) that more errors occurred in non-final weak syllables than stressed syllables. Further, it highlights the necessity of sampling non-final weak syllables and, therefore long words, given the particular difficulty posed by non-final weak syllables for children with impairment. Aguiluar-Mediavalla et al. (2002, p. 573) noted this when they stated that "There is a simplification process that seems to be more prevalent in these children (with specific language impairment or language delay) than in their language level controls, namely, the deletion of unstressed syllables, mainly initial ones."

The observation that much of the consonant deletion was associated with the requirement for anterior-posterior articulatory movements that co-occurred with non-final weak syllables is consistent with Gilbert and Johnson's (1978) findings. Their typically developing 6- and 7-year-olds had difficulty imitating PSWs containing C+/jul/ sequences requiring an anterior-posterior movement and weak syllables, such as in the word *binoculars*. Two mismatches of *ambulance,* [æmbələns] and [æmbliəns], in the current study matched the patterns that they described for their participants for other PSWs with these features.

The observation that much of the consonant deletion was associated with the sonorant sounds of /m/ and /j/ that co-occurred with non-final weak syllables is consistent with a report by Kehoe and Stoel-Gammon (1997). They reported that toddlers deleted non-final weak syllables with more sonorous onsets and codas more frequently than obstruent onsets and codas.

Frequency of Consonant Deletion

Syllable effects

In addition to the significant statistical result, the syllable effect was also indicated by more participants using consonant deletion in DSWs and PSWs than in MSWs and consonant deletion affecting relatively more PSWs (85%) than DSWs (42%) which, in turn, were affected more often than MSWs (26%). Even so, the significance of this syllable effect is weakened because consonant deletion did not increase linearly with increasing numbers of syllables. Rather most consonant deletion occurred in equal percentages across DSWs and PSWs (46% versus 47% respectively). Also, 4 words; 2 PSWs and 2 DSWs, accounted for more than 50% of all consonant deletion (*pumpkin* (26%), *ambulance* (19%), *husband* (6.7%) and *vegetables* (4.2%)) and, in all, consonant deletion was generally associated with a circumscribed group of words sharing common features. Consequently, a conclusion that better fits the data than an overall syllable effect is that the syllable effect is a proxy for a complex interaction of segmental and prosodic features that include two or more syllables, non-final weak syllables, sonorant sounds and within-word consonant sequences requiring anterior-posterior movements.

Age effects

In addition to the significant result, the age effect was also indicated by an inverted U-shape in that the number of words consonant deletion affected initially increased with age, peaked at about 5 years and then decreased. Secondly, the percentage of participants using consonant deletion in the top ranked words also decreased with increasing age. Specifically, the percentage of participants using consonant deletion in *pumpkin* and *ambulance* decreased with increasing age contemporaneously with increasing percentages of participants using the adult form of these words with increasing age. However, as less than 40% of 7-year-olds said these words in the adult manner, it is not possible to disambiguate whether this means that participants had not mastered the production of these words or whether speech variation effects were present. Likewise, the percentage of participants using consonant deletion in *husband* decreased with increasing age initially then remained static at about 25%. This could also mean speech variation associated with the /nd/ cluster. It could be that this consonant deletion is context-sensitive (Clark & Yallop, 1995) deletion rather than developmental deletion and if so should be excluded from consideration. If this is so then the consonant deletion from the /nd/ sequence in *behind* should also be excluded. Thus, an age effect is present because consonant deletion decreased with increasing age overall, within words and across words. To confirm the effects in *pumpkin, husband* and *ambulance* are developmental necessitates further study of children older than 7;11 years to determine if the occurrence of these immature patterns continues to decrease with increasing age.

Interaction effects

An interaction effect between the number of syllables and age seems to indicate that the participants were still mastering the ability to represent all consonants in the output in citation form PSWs and DSWs words up to 7;11 years of age but that they have mastered this control in MSWs by 4;11 years.

Developmental implications

In terms of speech processing, these patterns of consonant deletion imply that the older participants' phonological representations of words were better specified for consonants than the younger participants, allowing for the presence of more consonants in the output (Edwards & Lahey, 1998; Stackhouse & Wells, 1997). In addition, the asymmetry of consonant deletion resolution across words implies that MSWs were specified for consonants at younger ages than the DSWs and PSWs were. It can also be inferred that the DSWs and PSWs with non-final weak syllables, more sonorant sounds, within-word consonant sequences and requiring anterior-posterior articulatory movements were less well specified than the other DSWs and PSWs and this may account for the poorer production of these words. The confluence of these factors reduces syllable prominence making them perceptually weaker than other syllables (Kehoe, 2001). This in turn may preclude extraction of features to the same level of detail that can be extracted for other words, resulting in a relatively more holistic phonological representation. This more holistic representation may compromise the remainder of the speech processing chain, culminating in an output of diminished accuracy. For accurate production of perceptually weak constituents, children may need to be aware of the constituents of words at a finer level of detail than for words with constituents that are relatively more salient. It may be that they need to acquire something almost akin to *phonemic awareness*, that is, the explicit awareness that words are comprised of individual phonemes (Gillon, 2004).

Clinical applications

Occurrence of consonant deletion outside the ranges described herein may indicate impairment. Thus one or two instances of consonant deletion in *ambulance* and *pumpkin* is probably typical behaviour for children aged 3 to 7 years, as is one or two instances of consonant deletion by children aged 3 to 7 years in the PSWs listed in Table 7. However, 4 or more occurrences of consonant deletion from the listed words, with the exception of *husband* or from the /nd/ sequence in *behind* may indicate impairment. Further, the skewed distribution of consonant deletion means that the median scores should be used in clinical decision making not means and standard deviations. Also occurrence of the phonological processes, final consonant deletion and cluster reduction in word initial and final position beyond the age of 4 years is not expected and occurrence may indicate impairment.

The results of this study coupled with the information from the literature imply that PSWs should be a part of routine speech assessment as they appear to provide unique information about speech acquisition and possibly speech processing. Exclusion of them from assessment risks missing children with impairment in speech, language or literacy. This suggests the need to move from the reliance on the use of speech tests with few PSWs in practice (Skahan, Watson, & Lof, 2007) and policy (Department of Education and Children's Services, 2006) and supports the recommendation of Young (1995) and Stackhouse (1985) to use them routinely.

Conclusions

Consonant deletion is a common but low frequency behaviour in typically developing speech over the age span of 3;0 to 7;11 years that occurs in a circumscribed group of DSWs and PSWs. These words contain two or more syllables, sonorant sounds, non-final weak syllables, within-word consonant sequences and a need for anterior-posterior articulatory gestures. This study supported all three hypotheses that consonant deletion increases as the number of syllables in words increases, decreases as age increases and that age and syllable numbers interact. However, the syllable effect was qualified to be a proxy for a complex interaction of segmental and prosodic features rather than a pure effect. These words provide unique information about children's speech skills and, consequently, it is recommended that these words and PSWS are a part of routine assessment of speech.

Acknowledgments

This work forms part of the first author's PhD undertaken at The University of Sydney and supervised by the remaining authors. The authors wish to acknowledge the Channel 7 Children's Research Foundation for funding this research. They also wish to thank two anonymous reviewers for their comments on earlier drafts of this paper.

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Appendix. Consonant deletion in mono-, di- and poly-syllabic words

Monosyllabic words					**Disyllabic words**					**Polysyllabic words**				
Word	**No**	**O**	**%**	**Rel%**	**Word**	**No**	**O**	**%**	**Rel %**	**Word**	**No[1].**	**O**	**%**	**Rel %**
1. bridge*	1	264	0.4	<0.1	1. behind	20	647	3.1	1.7	1. ambulance*	186	264	70.1	16
2. dress*	3	264	1.1	0.2	2. boiling*	1	264	0.3	<0.1	2. animal✦s	0	647	0	0
3. drink	15	283	5.0	1.3	3. blanket*	1	264	0.3	<0.1	3. banana	1	283	0.4	<0.1
4. drive*	3	264	1.1	0.2	4. breakfast	31	283	11.0	2.6	4. broccoli*✦	30 (18)	590	5.1	2.5
5. green	1	283	0.4	<0.1	5. brother	2	283	0.7	0.2	5. bulldozer*	0	264	0.0	0
6. horse	1	283	0.4	<0.1	6. flower	3	283	1.0	0.3	6. butterfly✦	33 (24)	647	5.1	2.6
7. jump	1	283	0.4	<0.1	7. garden	1	283	0.3	<0.1	7. caravan	7	283	2.4	0.6
8. left*	1	264	0.4	<0.1	8. giraffe✦	1	647	0.2	<0.1	8. caterpillar	8	283	2.8	0.7
9. nose	1	283	0.4	<0.1	9. husband*	78	264	30.1	6.7	9. cauliflower*	5	264	1.8	0.4
10. play*	1	264	0.4	<0.1	10. ice-cream*	5	264	1.8	0.4	10. celery*✦	12 (8)	590	2.0	1.0
11. queen	2	283	0.8	0.1	11. lettuce*✦	1	590	0.2	<0.1	11. computer	23	283	8.1	1.9
12. snail	1	264*	0.4	<0.1	12. lunch box*	1	264	0.3	<0.1	12. crocodile	12	283	4.2	1.0
13. sneeze	1	264*	0.4	<0.1	13. monkey*✦	2	590	0.4	0.2	13. cucumber*	9	264	3.4	0.8

14. soft	1	264*	0.4	<0.1
15. spoon	1	283	0.4	<0.1
16. stove	2	283	0.8	0.1
17. straw	10	283	4.0	0.8
18. train	2	283	0.8	0.1
19. yolk	15	264*	5.7	1.3

14. mushroom	3	283	1.0	0.3
15. music	36	283	13.0	3.1
16. pumpkin✦	301 (195)[1]	647	46.5	26.0
17. robot*	1	264	0.3	<0.1
18. rubbish	1	283	0.3	<0.1
19. sandwich	12	283	4.2	1.0
20. skateboard	7	283	2.4	0.6
21. skipping*	2	264	0,8	0.2
22. toadstool*	7	264	2.7	0.6
23. toothbrush	16	283	5.6	1.4
24. yellow	4	283	1.4	0.3
25. zebra✦	11	647	1.7	0.9

14. elephant✦	21 (19)	647	3.2	3.8
15. escalators*	5	264	1.7	0.4
16. guinea pig	2	283	0.7	0.1
17. hairdresser	6	283	2.1	0.5
18. hamburger	3	283	1.1	0.2
19. helicopter	12	283	4.2	1.0
20. hippopotamus✦	13	647	2.0	1.0
21. magazine*	2	264	0.8	0.1
22. medicine*	10	264	3.7	0.8
23. octopus	2	283	0.7	0.1
24. parachute*	10	264	3.7	0.8
25. policeman*	0	264	0	0
26. potato*	3	264	1.1	0.2
27. pyjamas	2	283	0.7	0.1
28. sausages*	0	264	0	0
29. sleeping bags	7	283	2.4	0.6

			30. spaghetti	15	283	5.3	1.3
			31. stethoscope*	0	264	0	0
			32. television*	11	264	4.2	0.9
			33. tomato*✦	0	647	0.0	0
			34. umbrella	10	283	3.5	0.8
			35. vacuum cleaner	20	283	7.0	1.6
			36. vegemite*	0	264	0.0	0
			37. vegetables✦	49 (24)	647	7.5	4.2
			38. washing machine	13	283	4.6	1.1
			39. zucchini*	1	264	0.4	<0.1
Total	**63**	**549**		**543**			

Key: No=occasions of deletion; O=opportunities for consonant deletion %= the percentage of consonant deletion for that word; [1]numbers in parentheses indicate number of participants using consonant deletion adjusted for repeated words;* words not included for 3-year-olds; ✦ repeated words. Rel% = Percentage of all consonant deletion

Table 1. A summary of the frequency of singleton consonant deletion and cluster reduction in typically developing children

Age (Yrs)	Consonant deletion (%) frequency*	Percentage of children using consonant deletion	Authors	Cluster reduction (%) frequency*	Percentage of children using cluster reduction	Authors
2	6-25	86-90	(James, 2001a; Khan & Lewis, 1986; McCormack & Knighton, 1996; Preisser et al., 1988; Roberts et al., 1990; Watson & Scukanec, 1997b)	27-73	90-100	(James, 2001a; Khan & Lewis, 1986; McCormack & Knighton, 1996; McLeod, van Doorn, & Reed, 2001; Preisser et al., 1988; Roberts et al., 1990; Watson & Scukanec, 1997b)
3	2-25	80-100	(Haelsig & Madison, 1986; James, 2001a; Roberts et al., 1990; Vihman & Greenlee, 1987).	17-75	90-100	(Dodd et al., 2003; Haelsig & Madison, 1986; James, 2001a; Khan & Lewis, 1986; Roberts et al., 1990; Vihman & Greenlee, 1987).
4	0-28	54	(Haelsig & Madison, 1986; Hodson & Paden, 1981;	0-28-	80-90	(Haelsig & Madison, 1986; Hodson & Paden, 1981; James,

			James, 2001a; Roberts et al., 1990).			2001a; Roberts et al., 1990).
5	1-14	57	(Haelsig & Madison, 1986; James, 2001a; Roberts et al., 1990)	7-10	<10-100	(Dodd et al., 2003; Haelsig & Madison, 1986; Ingram, Pittam, & Newman, 1985; James, 2001a; Khan & Lewis, 1986; Roberts et al., 1990).
6	0-5	40	(James, 2001a; Roberts et al., 1990)	2-7	<10 -100	(Dodd et al., 2003; Ingram et al., 1985; James, 2001a; Roberts et al., 1990)
7	0-2	50	(James, 2001a; Roberts et al., 1990)	2-4	2-100	(Dodd et al., 2003; Ingram et al., 1985; James, 2001a; Roberts et al., 1990)

Key: * based on the means cited in the studies

Table 2. Distribution of participants by age and gender

Age range	Age			Girls	Boys	Total
	Mean	SD	Range			
3;0-3;11	42.4	3.7	36-47	10	9	19
4;0-4;11	55.1	3.0	48-59	22	23	45
5;0-5;11	65.1	3.8	60-71	29	30	59
6;0-6;11	77.6	3.3	72-83	42	43	85
7;0-7;11	88.6	3.3	84-95	43	32	79
Total	77.0	14.5	36-95	146	137	283

Table 3. Median consonant deletion scores by word type

Age	N	All words			MSWs			DSWs			PSWs		
		M	R	%	M	R	%	M	R	%	M	R	%
3	19	6.7	1.0-20.2	95	0	0-13.9	42	10.5	0-23.7	95	10.0	0-30.0	79
4	45	3.0	0-17.7	98	0	0-2.7	20	4.3	0-15.7	89	5.5	0-40.0	96
5	59	2.2	0-8.9	97	0	0-6.9	15	3.2	0-11.4	86	2.1	0-29.1	83
6	85	1.6	0-6.4	93	0	0-1.4	15	3.2	0-7.9	80	2.1	0-8.5	74
7	75	1.6	0-4.4	89	0	0-1.4	12	3.2	0-7.4	72	2.1	0-8.5	72
All	283	2.2	0-20.2	94	0	0-13.9	17	3.2	0-23.7	82	2.1	0-40.0	79

Key: Age= Age in years; N= Number of participants; MSWs = monosyllabic words; DSWs = disyllabic words; PSWs = polysyllabic words; M=Median; R=Range; %=Percentage of participants

Table 4. Post hoc testing of age effects for consonant deletion for MSWs, DSWs, PSWs

Age	3	4	5	6	7
3					
4	- D -				
5	M D P	- - P			
6	M D P	- D P	- - -		
7	M D P	- D P	- D P	- - -	

Key. Age in years; M, D, P = significant comparisons for MSWs, DSWs, PSWs respectively

Table 5. Types of consonant deletion

Age	N	Cluster reduction			Consonant sequence reduction			Intervocalic consonant deletion		
		M	R	%	M	R	%	M	R	%
3	19	1.3	0.3-4.3	100	0.3	0-1.5	63	0	0-2.2	32
4	45	0.7	0-3.5	98	0	0-1.1	49	0	0-1.0	40
5	59	0.5	0-2.8	95	0	0-0.7	30	0	0-1.0	25
6	85	0.5	0-2.7	87	0	0-0.7	29	0	0-0.4	23
7	79	0.4	0-1.3	86	0	0-0.4	11	0	0-0.5	6
All	283	0.5	0-4.3	91	0	1-1.5	30	0	0-2.2	23

Key. Key. Age= Age in years; N= Number of participants; M=Median; R=Range; %=Percentage of participants

Table 6. Consonant deletion scores by word type

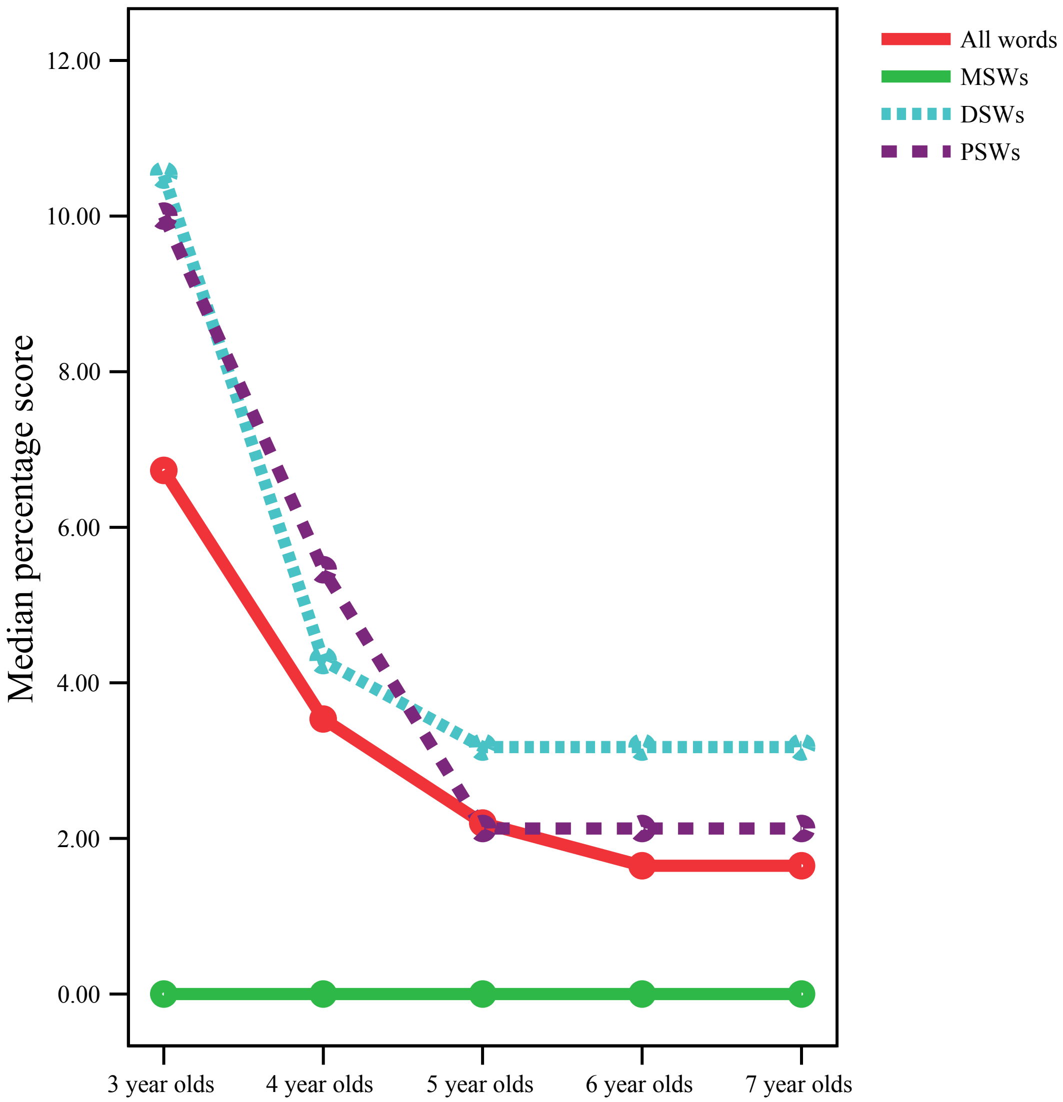
Age	N	All words			MSWs						DSWs						PSWs					
					SI			SF			SI			SF			SI			SF		
		M[3]	R[4]	%[5]	M	R	%	M	R	%	M	R	%	M	R	%	M	R	%	M	R	%
3	19	9	2-30	95	0	0-64	37	0	0-100	10	10	0-57	84	43	57	84	10	40	73	0	0	0
4	45	6	29	98	0	11	11	0	17	2	0	43	19	20	40	87	6	56	93	0	10	4
5	59	4	24	97	0	27	9	0	33	2	0	21	27	14	56	84	6	39	77	0	13	6
6	85	5	23	93	0	13	4	0	17	5	0	15	15	25	50	73	6	44	67	0	13	3
7	79	3	11	89	0	7	3	0	0	0	0	8	9	12	63	64	6	13	60	0	13	3
All	283	4.5	30	94	0	7.4	8	0	1.4	8	0	4.2	22	1.0	3.3	78	0.5	4.6	72	0	0.9	4

Key: Age= Age in years; N= Number of participants; MSWs = monosyllabic words; DSWs = disyllabic words; PSWs = polysyllabic words; M=Median; R=Range; %=Percentage of participant; SI=syllable initial; SF=syllable final

Table 7. The words affected by consonant deletion

PSWs (n=32)	**ambulance**, *vegetables elephant, butterfly, broccoli, computer, vacuum cleaner, spaghetti, washing machine,* (*celery, crocodile, helicopter, hippopotamus*), television, cucumber, (medicine, parachute), umbrella, caterpillar, (caravan, sleeping bags), hairdresser, cauliflower, escalators, (hamburger, potato), magazine, (guinea pig, octopus, pyjamas), (banana, zucchini)
DSWs (n=28)	**pumpkin, husband**, *music, breakfast, behind, toothbrush, sandwich*, toadstool, skateboard, ice-cream, zebra, yellow, (flower, music), skipping, brother, monkey (boiling, blanket, garden, lunch box, monkey, mushroom, robot, rubbish), (giraffe, lettuce)
MSWs (n=19)	*yolk, drink*, straw, (dress, drive), (queen, stove, train), (bridge, green, horse, jump, left, nose, play, snail, sneeze, soft, spoon)

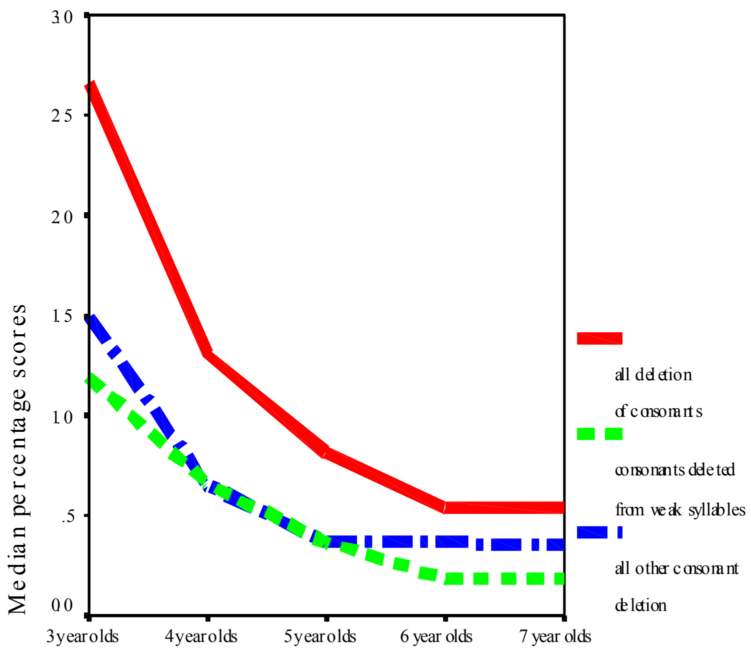
Key. MSWs = monosyllabic words; DSWs = disyllabic words; PSWs = polysyllabic words; tied words are in parentheses; emboldened words together accounted for 49% of all consonant deletion; italicised words each accounted for 1% to 4.9% of all CD; each of the remaining words account for less than 1% of all CD



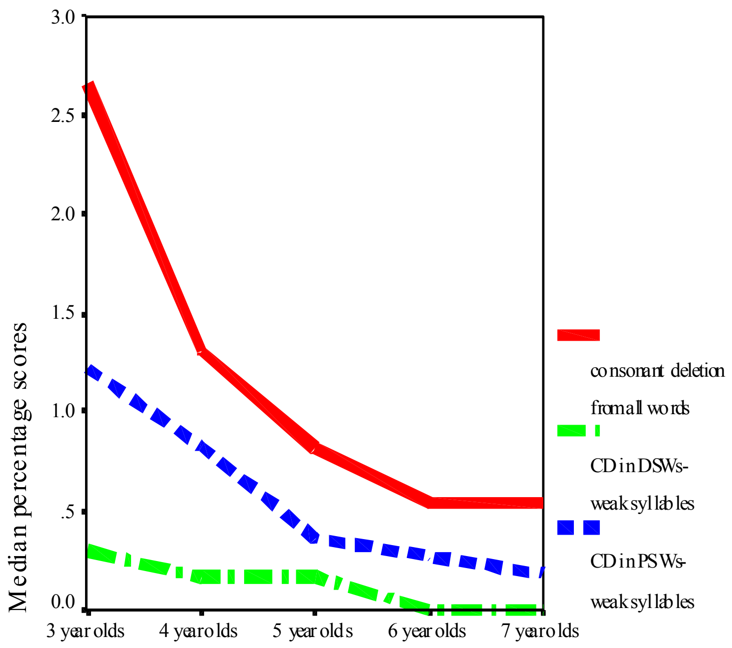
Key: MSWs = monosyllabic words; DSWs = disyllabic words; PSWs = polysyllabic words

Figure 1. Median percentage frequency of consonant deletion by word type

2a All consonant deletion



2b Consonants deleted from weak syllables in di- and polysyllabic words



Key: DSWs = disyllabic words; PSWs = polysyllabic words

Figure 2. Consonants deleted from weak syllables. The percentage of deleted consonants was calculated using all consonants rather than the number of words.