Does the number of syllables in words affect weak syllable deletion in typically developing children aged 3 to 7 years speaking Australian English?

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Phonological process analysis is widely used to determine paediatric speech status. One process is weak syllable deletion (WSD) The hypothesis this study supported was a syllable number effect on the frequency of WSD occurrence. The participants, 283 randomly sampled, South Australian children, aged 3;0 to 7;11 years, speaking Australian English with proven normal language, cognition and hearing, named pictures yielding 166 words. All vowels and consonants were repeatedly sampled in all syllable positions in words varied for syllable number, stress and shape. The results also showed that WSD of final weak syllables (*jump*er) had remitted by the age of three years. However, deletion of non-final weak syllables (*giraffe*, *hippopotamus*) was a low frequency but common process in the speech of children from 3 to 7 years, with significant age effects present up to the age of 7 years. Qualitative analysis of the data indicated that the syllable effect was a proxy of word complexity that included the number of syllables, non-final, extrametrical or unfooted weak syllables, liquid consonants and voiceless obstruent onsets.

Children with communication impairment (CI) usually have more mismatches in their speech output than typically developing children. One pattern of mismatches is weak syllable deletion (WSD).

WSD occurs in the speech of children with (1) speech impairment (SI) and normal language (Klein & Spector, 1985; Leitão, Hogben, & Fletcher, 1997a; Rvachew & Andrews, 2002; Yoss & Darley, 1974), (2) language impairment (LI) and normal speech (Leitão et al., 1997a), (3) speech and language impairment (S&LI) (Aguilar-Mediavilla, Sanz-Torrent, & Serra-Raventos, 2002; Bradford & Dodd, 1997; Carter & Gerken, 2003; Chiat & Hunt, 1993; Leitão et al., 1997a; Lewis, 1990; Panagos & Prelock, 1996, , 1997; Sahlén, Reuterskiöld Wagner, Nettelbladt, & Radeborg, 1999b), (4) literacy impairment (Kamhi & Catts, 1986; Katz, 1986; Leitão et al., 1997a) and (5) phonological processing impairment (Kamhi & Catts, 1986; Katz, 1986; Leitão et al., 1997a).

Across all these types of CI, WSD usually affected non-final weak syllables (NFWS) rather than final weak syllables (FWSs). NFWSs are the initial WSs (IWS) that occur in disyllabic words (DSWs) and [1]polysyllabic words (PSWs) such as *giraffe* and *spaghetti*, and the within-word WSs (WWWS) that can only occur in PSWs such as in *telephone* and *hippopotamus.*

WSD occurs in the speech of typically developing children, aged one to seven years, as summarised in Tables 1 and 2. Further, typically developing children, like children with CI, delete NFWSs more frequently than final ones (Allen & Hawkins, 1980; Carter & Gerken, 2004; Echols, 1993; Echols & Newport, 1992; Elbert & Gierut, 1986; Fikkert, 1994; Gerken, 1994; Kehoe, 1998; Kehoe & Stoel-Gammon, 1997a, , 1997b; Klein, 1981, , 1981b, , 1982; Pater, 1997; Vance, Stackhouse, & Wells, 2005; Young, 1991). Additionally, NFWSs in

[1] The term, polysyllabic words, is used to denote words containing three or more syllable. The term, multisyllabic words (XSWs), is used as a collective term to refer to DSWs and PSWs.

PSWs are deleted more frequently than in DSWs (Echols & Newport, 1992). Variability is conspicuous in the summaries in Tables 1 and 2 about the frequency of occurrence of WSD, the numbers of children using it and its age of resolution. Some of this variation is attributed to the numbers of PSWs and NFWSs sampled. In studies where five or more PSWs and NFWSs were sampled, WSD occurrence and the numbers of children using it (if reported) were higher and the age of resolution was later (Echols & Newport, 1992; Haelsig & Madison, 1986; James, 2001a; Vihman & Greenlee, 1987) than in studies where four or fewer PSWs and NFWSs were sampled (Dodd, Holm, Hua, & Crosbie, 2003; Khan & Lewis, 1986; Roberts, Burchinal, & Footo, 1990).

Thus, WSD occurs in typically, and atypically, developing speech. Its use is influenced by the numbers of syllables in words and the serial position of the WS in words. Patterns of WSD use in CI may differ to that in typically developing speech becasue 4-year-olds with S&LI deleted more WWWS and fewer IWS than typically developing children did (Carter & Gerken, 2003). The aim of this study is to determine the influence of these two variables on the occurrence of WSD. If WSD marks CI and it occurs in typically developing speech over the age span of 3 to 7 years, then it is important to be able to differentiate typical WSD from atypical WSD. This study will delimit some of normal variation of WSD.

Table 1 .Frequency of use of WSD by age

Age (Yrs)	WSD (%) frequency	Number children using WSD (%)	Authors
1	51	100	(Echols & Newport, 1992)
2	3-65	85	(Allen & Hawkins, 1980; James, 2001a; Khan & Lewis, 1986; McCormack & Knighton, 1996; Preisser, Hodson, & Paden, 1988; Roberts et al., 1990; Watson & Scukanec, 1997b)
3	2–75	10-90	(Allen & Hawkins, 1980; Dodd et al., 2003; Haelsig & Madison, 1986; James, 2001a; Roberts et al., 1990; Vihman & Greenlee, 1987; Watson & Scukanec, 1997b).
4	2-28-	10-54	(Dodd et al., 2003; Haelsig & Madison, 1986; James, 2001a).
5	1-19	29-50	(Dodd et al., 2003; Haelsig & Madison, 1986; James, 2001a)
6	0.2	10	(James, 2001)
7	1	25	(James, 2001)

Table 2.Age of resolution of WSD

Age (Yrs)	Authors
3	(Khan & Lewis, 1986; Preisser et al., 1988; Roberts et al., 1990; Stoel-Gammon & Dunn, 1985; Watson & Scukanec, 1997b)
4	(Dodd et al., 2003; Grunwell, 1981)
5+	(Dodd et al., 2003; Haelsig & Madison, 1986; James, 2001a)

Method

This study uses data from a pre-existing data base developed when standardising *the Assessment of Children's Articulation and Phonology (ACAP)*, (James, 2006). Data from Part 1, naming of pictures to give 166 words, and Part 3, repetition of 16 words to examine stability of word production, are discussed.

Participants

The randomly sampled participants were 283 typically developing South Australian children, aged 3 to 7 years, with proven normal hearing, language and cognitive skills (for further details see (James, 1999; James, 2001; James, McCormack, & Butcher, 1999). The sample matched the South Australian demography for rural, urban and suburban location and socio-economic status.

Table 3. 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	32	32	64
6;0-6;11	77.5	3.2	72-83	40	44	84
7;0-7;11	88.8	3.4	84-95	42	29	71
Total				146	137	283

Speech stimuli

The WSs sampled in ACAP are displayed in Table 4. The opportunities vary for different age groups because participants aged four years and older did the full form of the test whereas the 3-year-olds did the screening form. Part 3 was administered twice to the 3-, 4-years-olds and 5-year-olds attending kindergarten and once to all other participants.

Table 4. Weak syllables in Parts 1 and 3 of ACAP

Age (in years)	DSWs Initial WS	Final WS	PSWs Initial WS	Within WS	Final WS	All WS	NFWS
3	4	19	3 (4)	27	27	80	34
4	4	46	11	42	29	132	57
5 (PS)	4	46	11	42	29	132	57
5 (S)	3	41	10	34	25	113	47
6	3	41	10	34	25	113	47
7	3	41	10	34	25	113	47

Key: WS weak syllables; NFWS = non-final weak syllables; PS= preschool. S=School

Procedure

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

Data Analysis

Speech was broadly transcribed and then coded for the presence of WSD. WSD was only counted for *pyjamas* said as / / when WSD occurred in other words for the same participant, otherwise it was ignored, assuming it was a frozen form (Ozanne, 1995).

Reliability

Reliability of the transcribed data was 88% to 95% (See (James, 2006)) An experienced speech pathologist coded 10% of the data for WSD and the level of agreement was 94%.

Results

About two thirds of the participants (173/283) used WSD. They used it 555 times; 439 times in 26 of the 39 PSWs and 116 times in 2 of the 56 DSWs, affecting IWSs 273 times, WWWSs 281 times and FWSs 3 times. Individual use varied from zero to 12 times, as displayed in Figure 1. The distribution of scores is positively skewed, confirmed by the Kolmogorov-Smirnov test of normality. There were two occasions occurred when the stressed syllables were deleted from *engine* and *cucumber* by a 4- and 5-year-old respectively.

Words affected by WSD

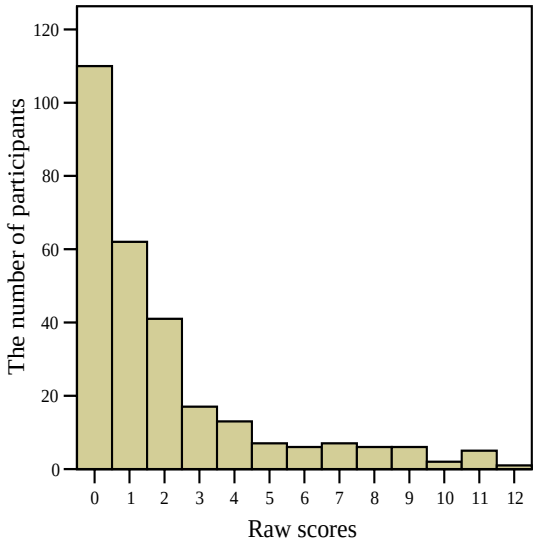
WSD usually affected NFWS because all but three occurrences affected them. The 26 affected words were the only two iambs, *behind* and *giraffe*, all nine PSWs with an IWS, 15 of the 25 PSWs with a WWWS and three of the 27 words with final WSs (once each), as detailed in Figure 2 and Tables 5 and 6.

Occurrences of non-final WSD varied across words, varying from 23% of all occasions for *broccoli* to 0.2% for *caterpillar*. Affected words are listed in descending order with tied words in parentheses, with rates of WSD for individual words in Table 6.

broccoli, giraffe, policeman, computer, pyjamas, spaghetti, hippopotamus, tomato, animals, behind, potato, caravan, ambulance, (celery, medicine), butterfly, (banana, magazine, vegetables), (helicopter, umbrella[2]), elephant, (sausages, washing machine, zucchini), caterpillar

The first nine listed words accounted for 80% of all WSD contrasting with the remaining 17 words that accounted for 20%. The first two words accounted for 43% of all WSD.

Figure1. The distribution of the WSD raw scores



[2] Final WSD occurred on one rendition of *umbrella*

Figure 2. Median percentage use of WSD by serial position in XSWs

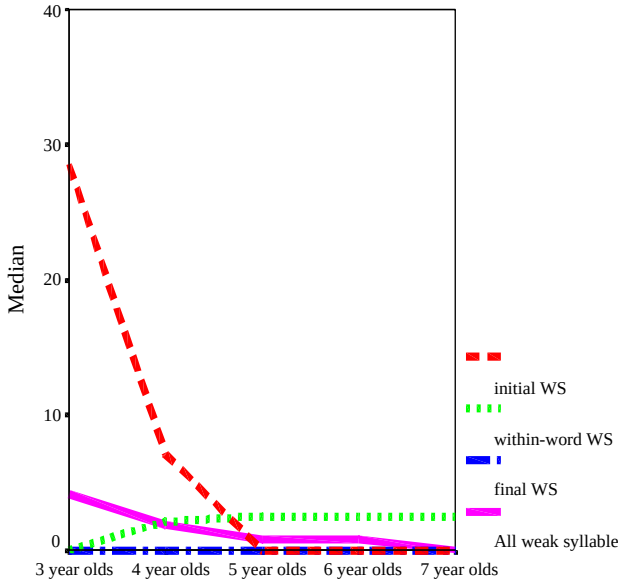


Table 5. Serial positions from which syllables were deleted from PSWs

Age	PSWs							
	Initial WSD				Within-word WSD			
	O	Median (%)	Range[1] (%)	Percentage[2]	O	Median %	Range (%)	Percentage
3	7	3.70	0-11 (3)	53	27	7.40	0-33 (9)	79
4	14	2.38	0-26 (7)	62	42	2.40	0-14 (6)	62
5	12	0.00	0-10 (4)	27	36	2.40	0-21 (7)	54
6	12	0.00	0-18 (6)	27	36	0.00	0-12 (4)	31
7	12	0.00	0-3 (1)	4	36	0.00	0-11 (4)	30

Key: O=opportunity [1]First number is the range expressed as a percent and number in parentheses represents upper raw score; [2]Percentage of participants

Table 6. Weak syllable deletion in all polysyllabic words and affected DSWs

Word	IWS	WWWS	O	%	Word	IWS	WWWS	O	%
ambulance*	0	9	264	3.4	hippopotamus	0	45	647	6.9
animals	0	32	647	4.9	magazine*	0	2	264	0.8
banana	2	0	264	0.8	medicine*	0	5	264	1.9
behind	13		283	4.5	octopus	0	0	283	0.0
broccoli*	0	133	590	22.5	parachute*	0	0	264	0.0
bulldozer*	0	0	264	0.0	policeman*	36	0	264	13.7
butterfly	0	8	647	1.2	potato*	11	0	264	4.20
caravan	0	11	283	3.8	pyjamas	29	0	283	10.24
caterpillar	0	1	590	0.2	sausages*	0	1	264	0.4
cauliflower*	0	0	264	0.0	sleeping bags	0	0	283	0.0
celery*	0	11	590	1.9	spaghetti	20	0	283	7.1
computer	30	0	283	11.0	stethoscope*	0	0	264	0.0
crocodile	0	0	283	0.0	television*	0	0	264	0.0
cucumber*	0	0	264	0.0	tomato*	17	0	264	6.4
elephant	0	4	647	0.6	umbrella	2	0	283	0.7
escalators*	0	0	264	0.0	vacuum cleaner	0	0	283	0.0
giraffe	103		647	16.0	vegemite*	0	0	264	0.0
guinea pig	0	0	283	0.0	vegetables	0	5	647	0.8
hairdresser	0	0	283	0.0	washing machine	0	10	283	0.4
hamburger	0	0	283	0.0	zucchini*	10	0	264	0.4
helicopter	0	2	283	0.7	shivering[1*]	0	4		
					Sub-totals	273	282		
					Total		555		

Key: IWS= initial weak syllable; WWWS=within word weak syllable; O = opportunities for WSD; % = percentage use of WSD; Shading denotes words with no non-final weak syllable; *words not included for 3-year-olds; [1]*Shivering* was not a target PSW but some participants

used it for the target DSW *shaking* so no number appears with it, cross hatching; no syllable relevant to DSW

The number of PSWs affected by WSD fluctuated with age, as displayed in Table 7, being greatest for 5-year-olds and least for 7-year-olds.

Table 7. Number and percentage of PSWs affected by WSD by age group

Age	Number	IWS			WWWS			Total		
		N	T	%	N	T	%	N	T	%
3* years	19	3	3	100	7	14	50	10	17	59
4 years	45	7	9	78	11	17	65	18	26	69
5 years	64	9	9	100	16	17	94	25	26	96
6 years	84	6	9	67	9	17	53	15	26	58
7 years	71	2	9	22	7	17	41	9	26	35

Key: Number = number of participants; N= number of words; T = total number of words that can be affected %= percentage of words; IWS= initial weak syllable; WWWS=within word weak syllable

Age and syllable effects

The relative occurrence of WSD was calculated in two ways. Firstly, all WSs in the word corpus, that is, all ISWs, WWWs final weak syllables (WSDall) were included and secondly, final WSs were excluded (WSDnf).

The percentage median of WSDall was 0.83% with a range from zero to 15% compared to 2.2% for WSDnf with a range from to zero to 32%, as displayed in Tables 8 and 9. Perusal of these tables reveals how WSD varied with age and syllable numbers, regardless of how WSD was calculated.

Table 8. Median percentage WSDall scores by word type

Age[1]	No[2]	XSWs				DSWs				PSWS			
		O	M[3]	R[4]	%[5]	O	M	R	%	O	M	R	%
3	19	82	4.2	0-15	89	31	3.2	0-10	53	51	3.9	0-20	84
4	45	124	1.9	0-8	82	52	0	0-8	42	78	2.2	0-10	84
5	64	108	0.8	0-8	66	45	0	0-7	38	63	1.3	0-11	56
6	84	108	0.8	0-9	54	45	0	0-4	20	63	0	0-13	46
7	71	108	0	0-3	44	45	0	0-4	13	63	0	0-5	34
All	283		0. 8	0-15	61		0	0-10	28		1.3	0-21	54

Key: [1]Age in years; [2]Numbers of participants; O=opportunities; [3]Median; [4]Range; [5]Percentage of participants

Table 9. Median percentage WSDnf scores by word type

Age[1]	No[2]	XSWs				DSWs				PSWS			
		O	M[3]	R[4]	%[5]	O	M	R	%	O	M	R	%
3	19	27	8.8	0-33	89	3	25	0-75	53	24	6.7	0-33	84
4	45	60	7.1	0-33	82	4	0	0-100	42	56	4.2	0-21	84
5	64	40	2.2	0-22	66	2	0	0-100	38	48	2.3	0-19	56
6	84	40	2.2	0-24	54	2	0	0-67	20	48	0	0-23	46
7	71	40	0	0-9	44	2	0	0-67	13	48	0	0-9	34
All	283		2.2	0-32	61		0	0-100	28		2.3	0-33	54

Key: [1]Age in years; [2]Number of participants; O= opportunities; [3]Median; [4]Range; [5]Percentage of participants;

Age effects

Age affected WSD, confirmed by the Kruskal-Wallis test. Significant effects existed for WSDall for XSWs ($\chi^{2=}$ 56.30; df =4; p<0.001), DSWs ($\chi^{2=}$ 29.85; df =4; p<0.001) and PSWs, ($\chi^{2=}$ 54.23; df =4; p<0.001). Significant effects also existed for WSDnf for XSWs ($\chi^{2=}$ 55.54; df =4; p<0.001), DSWs ($\chi^{2=}$ 25.68; df =4; p<0.001) and PSWs, ($\chi^{2=}$ 56.213; df =4; p<0.001).

WSD steadily declined with increasing age, regardless of calculation method, indicated by the NP trend test (Cuzick, 1985) (WSDall for XSWs z= -7.39, p<0.01; DSWs (z= 5.37, p<0.01 and PSWs z= -7.21, p<0.01 and WSDnf for XSWs z= -7.38, p<0.01; DSWs z= -4.97, p<0.01 and PSWs z= -7.31, p<0.01). Also, differences existed between some age groups using the Mann-Whitney U test with a modified Bonferroni adjustment, summarised in Table 10.

Table 10. The significant differences between age groups

WSDall		WSDnf	
DSWs	PSWs	DSWs	PSWs
3 v 4	3 v 5	3 v 4	
5 v 7	3 v 6	5 v 7	3 v 6
6 v 7	3 v 7	6 v 7	3 v 7
	4 v 5		4 v 5
	4 v 6		4 v 6
	4 v 7		4 v 7
	5 v 7		5 v 7
			6 v 7

Syllable number effects

WSD was influenced by the number of syllables for WSDall and WSDnf, but with a higher Z score from the Wilcoxon signed rank test for WSDall (Z = -6.51; p<0.001) than for WSDnf (Z = -4.30; p<0.001). Differences existed between every age group for WSDall but only for the 5-year-olds for WSDnf (Wilcoxon signed rank test with a modified Bonferroni adjustment).

Discussion

About two thirds of the participants used non-final WSD about three times. Final WSD and deletion of stressed syllables were negligible, given they accounted for 1% of all occurrences of syllable deletion. To interpret the statistical age and syllables effects necessitates consideration of the data qualitatively as well as quantitatively.

Participants' use of WSD

The results from this study indicate that WSD is a feature of typically developing citation speech from 3 to 7 years of age. They are consistent with the results of other scholars (French, 1988; Haelsig & Madison, 1986; James, 2001a; Klein, 1985; Vihman & Greenlee, 1987; Young, 1991). However, they vary from the conclusions of others that WSD was rare in speech of 3-year-olds (Khan & Lewis, 1986; Roberts et al., 1990; Stoel-Gammon & Dunn, 1985) or 4-year-olds (Dodd et al., 2003; Grunwell, 1981; Hodson & Paden, 1981).

The number of children using WSD

In this study, WSD is common in citation form speech because the majority of participants used it, varying from 89% of 3-year-olds to 53% of the 7-year-olds. This finding is consistent with the findings of other scholars for 3- to 5-year-olds. (Haelsig & Madison, 1986; James, 2001; Vihman & Greenlee, 1987). However more 6- and 7-year-olds used WSD in the present study than in another study that James (2001a) conducted with other South Australian children. These differences were attributed to the greater numbers of NFWSs in this study.

The frequency of use of WSD

WSD occurs infrequently, indicated by the group median of 2.2%. This finding is consistent with the findings of Khan and Lewis (1986) and James (2001c) but lower than the findings

reported by Dodd et al. (2003) for 3-year-olds and Haelsig and Madison (1986) for 3-, 4- and 5-year-olds (24% (mean) & 27, 17 and 9% (medians) respectively). These higher scores were attributed to the combined use of *giraffe* and few words with NFWSs in their protocols. Given *giraffe* was frequently affected by WSD in this study and that of Young's (1991), its presence may inflate scores, especially when only three or four other NFWSs are sampled.

Distribution

The distribution of scores was positively skewed. This distribution pattern cannot be compared with other studies because it was not reported. However, the distribution derived from the data that Haelsig and Madison (1986) provided was also positively skewed, confirmed by the Kolmogorov-Smirnov test of normality. This skewed pattern present in two studies that sampled more than four NFWS implies this is the usual pattern of WSD.

The words affected by WSD

A conspicuous feature of WSD in this study was its variability across words. However, this variability is consistent with the findings of others for children aged 1;5 to 4;0 years (Echols & Newport, 1992; Kehoe, 2001; Young, 1991). T

This uneven use of WSD infers factors other than the numbers of syllables in words triggers WSD. The phonological factors common to the affected words were NFWSs in initial word position or that were extrametrical or unfooted, liquid consonants and voiceless obstruent onsets. Aggregation of these factors within one word was associated with higher use of WSD across participants as seen with *broccoli* and *giraffe.* This constellation of factors associated with WSD matches those Kehoe (2001; 1997b) isolated and corroborates and supports her conclusion that syllable prominence, the sonority of segments and edge-based factors interact and influences deletion rates of NFWSs.

Age and syllable effects

The two ways of calculating the relative use of WSD resulted in different interpretations of the syllable effect. For WSDall (inclusion of final weak syllables), all age groups differed from one another, implying that the rate of WSD was higher in PSWs than in DSWs for every age group. By contrast, only one age group, the 5-year-olds, differed when using WSDnf. This latter finding implies that up to the age of 5 years, NFWS production is difficult regardless of the number of syllables in words. At 5 years of age, a syllable number effect emerges, indicating that the participants had greater production control over WSs in DSWs than in PSWs. This difference disappears by the age of 6 years, indicating that there is still continued refinement of NFWSs in specific words

The implications from testing with WSDnf better fit the data than those from WSDall. They account for the large percentage of WSD (20%) that occurred in the DSW *giraffe;* the significant age effects present between 5-and 7-year-olds within DSWs and PSWs, that the number of PSWs affected increased from 3 to 5 years then decreased, and that *broccoli* and to a lesser extent *giraffe* accounted for an increasing percentage of all occasions of WSD as age increased; WSD in *broccoli* changed from 20% of the 4-year-olds to 50% of the 7-year olds and in *giraffe* changed from 24% of the 3-year-olds to 26% of the 5-year-olds. This finding may mean that in clinical practice, WSD should be calculated relative to NFWSs only. However, caution is required with this notion because DSWs and PSWs with IWSs were not matched for number, and further evidence may be needed.

The findings of negligible occurrence of final WSD and deletion of stressed syllables implies that by the age of three years, the lower limit of this data set, the participants children have mastered the production of final weak syllables, and stressed syllables. By contrast, participants were still mastering non-final weak syllable in XSWs up to the age of seven years

indicated by the age affects and the trend that WSD affects increasing numbers of PSWs up to the age of 5 years and then decreases.

The finding that the difficulty with WSs is with NFWSs rather than final ones accords with the consensus in the literature about this for children three years and younger (e.g. (Echols & Newport, 1992). The finding that acquisition of WSs continues from the age of three to five years both accords with the literature and clarifies some aspects of it. Whilst Dodd (1995), Haelsig and Madison (1986), and James (2001) all reported that children three years and older used WSD, the information from this study further delimits this by noting age effects extend to seven years, the limit of the data set, that it restricted to NFWS and that it occurred in a specific group of words. The apparent syllable effect is more likely to be a proxy for word complexity of which syllable number is one of many factors.

The notion that production of stressed and FWSs were mastered by the 3-year-olds indirectly accords with the findings of researchers who used four or fewer NFWSs to measure WSD because, by default, they reported on stressed and non-final syllables because so few NFWSs were sampled. This interpretation coupled with the evidence that the difficulty lies with NFWS implies that conclusions from these studies should be altered in the same way, that is, stressed and final weak syllables are not deleted from the age of 3 years.

These conclusions highlight how words in tests influence conclusions. If the XSWs used in this study were the 20 DSWs and five PSWS with FWSs, WSD would have occurred three times across two participants, with a conclusion that this pattern was insignificant. This conclusion would have been consistent with the notion that WSD disappears by 3 or 4 years. However, the inclusion of more than four PSWs with NFWSs in the study resulted in different conclusions about WSD than that in the literature for children older than 3 years.

In closing, WSD is a common occurrence in developing speech that occurs at low frequency. One or two occurrences of it in words from the aforementioned list are probably acceptable behaviour but variation outside these tolerances may be indicative of CI.

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