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Spontaneous word fragmentations in children: evidence for the syllable as a unit in speech production

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Part-word repetitions and word-internal pauses which occurred in two 2–3-year-old boys recorded spontaneous speech were analysed. A common framework for the assessment of these two types of fragmentations was employed in which interruptions of the articulatory process were distinguished from restarts. Interruptions occurred in monosyllabic as well as in polysyllabic words. In polysyllabic words interruptions mostly preserved CV(C) units. In these cases they were followed by immediate restarts i.e. the continuation of articulation from the point of interruption onwards. In cases where interruptions distorted CV(C) structure, a high proportion of retraced restarts was found. Retraced restarts involved either the word beginning (full retracing) or an intervocalic consonant directly preceding the place of interruption (partial retracing). These results support the hypothesis that the production of speech involves syllable-sized articulatory units. Supplementary results on the locations of speech interruptions show correspondences with results of elicited syllabification experiments. Some consequences for a theory of the development of speech production are discussed.

1. Introduction

Analyses of two corpora of child utterances aimed at establishing a possible relationship between speech dysfluencies and language development, revealed a considerable number of instances of disturbed speech in which words were unintentionally fragmented into smaller parts. These word fragmentations, occurring either in the form of word-internal pauses or of part-word repetitions, appear to constitute a valuable source of data for the exploration of speech production processes in children. Each fragmentation can be considered to proceed in two phases: (1) the *interruption*, i.e. stopping the articulatory process, and (2) the *restart*, i.e. the continuation of articulation. This study describes and analyses these two phases of fragmentation in terms of the structural properties of the words in which they occur. The primary goal of these analyses is to shed some light on the issue of *units* in speech production and their ontogenesis.

A discussion of production units in speech should acknowledge the distinction between *planning* and *execution* (Cohen, 1966). Speech planning is assumed to incorporate several

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processing stages, such as message generation, the construction of sentence frames that are able to convey the message structure, and the retrieval of words from lexical memory that adequately represent the relevant concepts (cf. Garrett, 1975; Levelt, 1983). The final result is a so-called "phonetic representation" of an intended stretch of speech. The execution of this speech plan involves the translation of the phonetic string into sets of neural commands for the articulators and articulation proper.

Speech error research suggests that the basic unit, i.e. the "chunk" of information that is operated upon as an indivisible whole, in computing the phonetic representation corresponds to the phoneme (Boomer & Laver, 1969; Fromkin, 1971; Shattuck-Hufnagel, 1983). Among the larger-than-phoneme elements the syllable has received considerable attention. However, intrusions and transpositions of syllables are so rare that one is inclined to dismiss the syllable as a planning unit. (Shattuck-Hufnagel, 1979, 1983). The role syllables play in speech planning seems to be confined to constraining the ordering of phonemes. It has repeatedly been established that the alternation of vowels and consonants, which is captured by the notion "syllable", is virtually never disturbed in speech errors. Moreover, in phoneme transpositions the syllabic positions of the reversed elements are almost always identical (Boomer & Laver, 1968; MacKay, 1970*a*). Another indication of the organizing role of syllabic structure is MacKay's (1972) finding that in blends of polysyllabic words (e.g. deportment + behavior → behortment) the source words were more often broken between syllables than within syllables (see MacKay 1982 for a theoretical account of these and related errors). Further speech error evidence (MacKay, 1972), as well as experimental results (Treiman, 1983), suggests that the constraining role of syllables in planning is implemented through the specification of phonemes as onsets, peaks and codas (cf. Fudge, 1969) in the phonetic representation.

On the level of speech execution there is an inclination to consider syllables as the best candidates for processing units. Fry (1964) has argued that the syllable captures the complex but harmonic co-operation of articulatory muscles which constitutes the rhythmical nature of speech. Thus, articulation can be thought to proceed in gestures of syllable size which are initiated by corresponding clusters of neural impulses (Shaffer, 1984). There appears to be no direct support for this hypothesis at the neuro-muscular level. Corroborative evidence is provided by studies on coarticulation (Fujimura, 1979), speech timing (cf. Farnetani & Kori, 1986; Nooteboom & Cohen, 1984) and allophonic variation (Maddieson, 1985). Moreover, research into speech synthesis indicates that concatenation of syllable-sized speech samples produces reasonably acceptable speech, whereas, for instance, phoneme concatenation requires excessive adaptation to produce similar results (Fujimura & Lovins, 1978). A model for the interface between speech planning and articulation which nicely agrees with the suggestions from speech synthesis has recently been proposed by Crompton (1982). Crompton argues that this interface, the "articulatory programmer", contains a library of syllable-sized articulatory routines which are addressed through a system based on the syllabic constituents onset, peak and coda, which are assumed to specify the ordering of units in the input phonetic representation.

Everything stated so far applies to the mature speech production system. Much less can be said about the development of speech production planning and execution. Apparently, slips of the tongue in children are either so infrequent (cf. Warren, 1985) or so difficult to spot amidst other imperfections that the question as to the development of planning units is still largely unanswered. The only systematic study to date was performed by MacKay (1970*b*), who analyzed some 23 spoonerisms observed by

R. Meringer in 3–6-year-old children. MacKay's results seem to imply that, just as in adults, phonemes are the planning units which are fitted into syllabic structures. However, although MacKay's results appear to be unequivocal with respect to the level of processing involved, they are not very informative from a developmental point of view as a result of not differentiating between ages.

Developmental data have been provided by experimental studies of word fragmentation in children. A general result of these studies is that the ability to break up words into syllable-sized units appears at an early age and before the ability to fragment syllables into phonemes (Liberman, Shankweiler, Fisher & Carter, 1974; Fox & Routh, 1975). The boundaries of the syllable-sized units which are produced by children in these tasks appear to be affected by various articulatory and suprasegmental attributes of the words (Fallows, 1981; Collier & De Schutter, 1985; van den Broecke & Westers, 1986). Treiman (1985) purports that, as an intermediate stage between word fragmentation into syllables and word fragmentation into phonemes, children are able to separate syllable onsets from rhymes.

Although these studies seem to point at a developmental priority of syllable sized units over phonemes, it is hard to establish on what processing level in speech production this developmental relation holds. Effects of articulatory factors are suggestive of the execution level. On the other hand, the deliberate nature of the task suggests the involvement of planning. There may even be a third possibility, since it has recently been argued that deliberate manipulation of speech may involve a level of representation distinct from those which function in normal speech production (Cowan, Braine & Leavitt, 1985). This "metaphonological" level of representation appears to integrate different strands of information that are relevant to the task at hand: articulatory, phonological, and even—at least in literate adults—orthographic. (cf. Cowan *et al.*, 1985; Collier & De Schutter, 1985; Read *et al.*, 1986). In summary it seems fair to state that the meaning of elicited fragmentation experiments, vis-à-vis the development of natural speech production processes and structures, is not easy to assess.

Spontaneous fragmentations—like the ones that will be presented below—do not seem to pose these interpretative problems. Since spontaneous fragmentations involve neither a spontaneous change of the speech plan—the parts that result from the fragmentation originate from the same word—nor an elicited manipulation, there is no need to assume that they refer to speech planning. Thus, the data that will be presented may be taken to primarily reflect properties of the *execution* level of speech production.

The aim of the present study is twofold. First, it attempts to provide new evidence for the claim that syllables are the basic units in speech execution. Second, the results will be compared to those of elicited fragmentation experiments in order to illuminate the correspondences and differences in spontaneous and elicited fragmentation. This is expected to contribute to a better understanding of the development of speech production.

2. Method

2.1. *Subjects*

The research project on speech disturbances and language development from which the present study originates makes use of tape recordings of speech delivered by two boys, N and T. A comparison of the ages and mean lengths of utterances (MLU, see Brown, 1973) presented in Table I indicates a difference in developmental rate between the two

TABLE I. An overview of the transcriptions constituting the corpora T and N

Week numbers	Total recording time (minutes)	Age (min/max) years; months-days	MLU (min/max)	Number of utterances
		Corpus T		
1–4	300	2; 3–22/2; 4–12	1.88–2.17	2050
9–12	240	2; 5–21/2; 7–6	2.09–3.24	2261
16–20	300	2; 8–2/2; 9–2	2.35–2.52	2675
24–26	210	2; 10–26/2; 11–22	2.61–2.86	1711
		Corpus N		
1–3	210	3; 0–21/3; 2–12	2.28–2.42	2291
7–10	240	3; 4–4/3; 5–0	2.31–2.58	3304
15–18	240	3; 6–0/3; 7–3	2.17–2.83	3964
21–25	300	3; 8–1/3; 10–17	2.93–3.89	4266

subjects. N was approximately nine months older than T during the recording period, but nevertheless, his MLUs show considerable overlap with those of T. Thus, N may be qualified as a "slow" language learner in comparison to T.

This characterization agrees with the differences in phonological development between the two children. At the time of the first recording N had a rather impoverished sound inventory, mainly characterized by pervasive fronting. However, during the period in which recordings were made this pattern was gradually replaced by a more mature phonological system. Presently, N's speech fully conforms to standards for children of his age. T on the other hand, showed a particularly rich speech sound inventory from the first recording session onwards.

2.2. *Recording and transcription*

An approximate total of 25 hours of recordings per child was collected. The recording sessions were evenly spread over time so that roughly one hour of tape became available for each week. The recordings were made under various ordinary domestic circumstances. Usually the children were engaged in a conversation with one of their parents. The recording equipment was of ordinary (non-professional) quality. It was usually placed in the direct vicinity of the child so as to optimally pick up the child's speech.

Approximately 17 hours of recordings per child were transcribed by two independently working, phonetically trained transcribers. The children's speech was broadly transcribed in IPA supplemented with nonstandard diacritics indicating dysfluencies and conspicuous aspects of prosody. The adult interlocutor's speech was written down in Dutch orthography. The transcribed tapes cover four 3–5 week periods which are evenly distributed over the total recording period (see Table I).

The independently produced provisional transcriptions of the children's utterances were compared to generate definitive versions. Discrepancies between the transcriptions were resolved by joint listening to the tapes and negotiation. If the transcribers could not reach agreement on either the segmental transcription or the identification of dysfluency, the disputed utterances or the relevant parts thereof were dismissed from subsequent analysis.

TABLE II. Some examples of the different classes of word fragmentations

Word-internal pauses (WIP):	
T032-134 frαxoto-cjə	(vrachtautootje/lorry)*
T241- 94 Rɔ-zεicjəs	(rozijntjes/raisins)
N101-149 hεis-tam	(hijskraan/crane)
Part-word repetitions:	
(a) word-initial (Rb):	
T031-147 f+fəlIndətjə	(vlindertje/butterfly)
N233- 30 tə+tIlətom	(telefoon/telephone)
(b) word-medial (Rm):	
T202- 12 tɔR+Rə	(toren/tower)
N181-126 pɔət+tInə	(boormachine/drill)
(c) word-final (Re):	
T162- 41 εyt+t	(uit/out)
N212-257 mαx+x	(mag/may)

*All examples are preceded by an indication of the corpus (T or N), the sequence number of the week (1–26), the sequence number of the episode within the current week, and the sequence number of the utterance. In parentheses: the intended word in Dutch and its English equivalent.

2.3. *Data classification and analysis*

Two types of speech disturbances were singled out for the purpose of this study, viz. part-word repetitions and word-internal pauses. Part-word repetitions involve the—literal—repetition of a word fragment consisting of one or several phonemes. This fragment can either be word initial, word medial or word final. Accordingly, the part-word repetitions have been labelled repetitions of word beginnings (Rb); word-medial repetitions (Rm) and repetitions of word endings (Re). In word-internal pauses (WIPs) words are fragmented by clearly discernable, dysrhythmic breaks in the pronunciation, usually accompanied by a silent interval of variable duration. Examples are given in Table II.

Although these two classes of fragmentations initially impress the observer as quite different they can easily be unified within a common process-oriented framework. In each fragmentation, two aspects can be discerned: the *interruption*, i.e. the point in the flow of speech where articulation breaks down; and the *restart*, i.e. the point where articulation is resumed (cf. Levelt, 1983). In a WIP, the interruption and the restart are located at the same point. Thus, the word "aardappel" (potato), pronounced /ardαpəl/, would be interrupted for instance after the /d/ and restarted at the /α/. In the remainder of the text, WIPs will be marked by dashes, as in /ard-αpəl/.

In repetitions of word beginnings, the word is interrupted "half way" and the restart involves backtracking to the word beginning. Thus, instead of continuing articulation at the /α/ upon an interruption after /d/, "aardappel" is restarted from its beginning. This is labelled a *fully retraced restart*. The transcribed examples of these instances mark the repetitions by a plus sign: /ard+ardαpəl/.

In word-medial repetitions the restart involves *partial* retracing, i.e. retracing to a point before the interruption but *not* to the beginning of the word. A partially retraced restart after the previously mentioned interruption of "aardappel", could for instance incorporate the /d/ only. This would be coded as /ard+dαpəl/.

Repetitions of word endings do not fit well in the interruption–restart framework because they occur after correct completion of the word. Consider for example the word-final repetition /ardαpəl+αpəl/. It is clear that the word "aardappel" is not interrupted at all. There is only a partially retraced restart which amounts to a kind of echo of the word's last portion.

Word-internal pauses and part-word repetitions in which the intended word could not be reliably reconstructed were discarded from the analyses. If several identical fragmentations—i.e. involving the same interruptions and restarts in the same words—followed one another directly within one utterance or in consecutive utterances, only the first one was included in data analyses. This was done to prevent "speech play" or practice sequences—which were known to occur occasionally—from exerting a biasing influence on the results.

3. Results

The total data set consists of 549 interpretable word fragmentations—370 in corpus T and 179 in corpus N. Repetitions of word endings are rare, less than 2% of all fragmentations. These will be excluded from further analyses.

A considerable number of fragmentations (39.4% in corpus T, 34.1% in corpus N) involve monosyllabic words. This finding clearly indicates that interruptions can distort syllables. However, Fig. 1 reveals a conspicuous difference in the distribution of the various fragmentation types over monosyllabic and polysyllabic words. Word-internal pauses (WIP) and word-medial repetitions (Rm) occur predominantly in polysyllabic words, whereas repetitions of word beginnings (Rb) more frequently occur in monosyllabic words. These distribution differences are significant in both corpora (T: $\chi^2 = 118.66$, df $= 2, p < 0.0001$; N: $\chi^2 = 74.04$, df $= 2, p < 0.0001$). In terms of the interruption-restarting framework, this result implies that an interruption of a polysyllabic word is

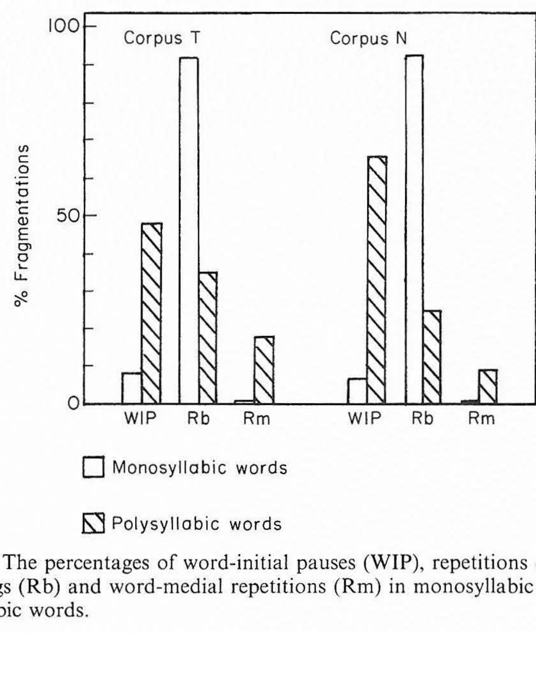

Figure 1. The percentages of word-initial pauses (WIP), repetitions of word beginnings (Rb) and word-medial repetitions (Rm) in monosyllabic and polysyllabic words.

usually followed by an immediate restart or a partial retracing (see examples 1–2), whereas interrupted monosyllables are usually restarted from the beginning (example 3).

(1) N161– 22	tɑpi-tɛin	(kapitein/captain)
(2) T251–174	swIŋ+ŋə	(zingen/sing)
(3) T011–104	s+sɔn	(zon/sun)

This finding should be evaluated in the light of the fact that an interruption in a monosyllabic word destroys the syllabic structure (by definition), whereas an interruption in a polysyllabic word may or may not do so. Thus, the tendency to fully restore a word upon its interruption may be affected by the degree of damage done to the syllables. The next section will go further into this by examining the interrelationships between interruption location and restarting in polysyllabic words. The remaining sections deal with some factors that may affect the exact localization of interruptions in both monosyllabic and polysyllabic words.

3.1. *Fragmentations in polysyllabic words*

Any attempt at exploring the interdependency of word fragmentation and syllabic structure inevitably leads to the problem of determining syllable boundaries. In order to know whether an interruption preserves or distorts a syllable, one would like to know where one syllable ends and the next one begins. However, there is no undisputable way of deciding this in advance for the present data. Phonological approaches to syllable boundaries are subject to controversy, and more importantly, they are based on data that are radically different from those analysed here. Therefore, an inductive approach will be pursued in order to derive a "behavioural definition" of the syllable and its boundaries (see also van den Broecke & Westers, 1986). A single presupposition underlies this approach, namely that vowels correspond to syllable cores and that consonant (-clusters) involve syllable transitions. The results of the present analyses may, and in fact will be compared to some phonological proposals concerning syllabification.

In the following discussion, interruptions are classified according to their position in the full IPA representation of the word as it would have been without fragmentation. Thus, interruptions that fall before, after or within intervocalic consonants or consonant clusters (henceforth: *intervocalic* interruptions, see examples 4–9) are distinguished from interruptions that fall either between or just after word-initial consonants, or just before or between word-final consonants (henceforth: *marginal* interruptions, examples 10–13). The position of an intervocalic interruption may be further specified according to whether the first segment that follows it (in the intact word) is a consonant (examples 4, 5, 8 and 9) or a vowel (examples 6 and 7).

(4) N233–294	pɑʃə-ti	(passagier/passenger)
(5) T251– 44	mɑn-daRɛi	(mandarijn/tangerine)
(6) N151– 43	taf+fo	(tafel/table)
(7) T044– 64	pipəm+mœncjə	(pepermuntje/peppermint)
(8) N242–410	pɑn+pɑntə	(panter/panther)
(9) T021– 12	pɑ+pɑpətɑp	(appelsap/apple juice)
(10) N233–176	pɑsitIn-s	(passagiers/passengers)
(11) T161–220	k-œʃə	(kusje/kiss)
(12) N222– 43	t+tesə	(deze/this)
(13) T101– 90	b+bebəcjə	(babietje/baby)

TABLE III. Observed and expected frequencies of three types of interruptions in polysyllabic words

		Marginal	Intervocalic/ consonant	Intervocalic/ vowel	Total
Corpus T:	Obs.	48(21.8%)	129(58.6%)	43(19.5%)	220(100%)
	Exp.	65(29.5%)	87(39.5%)	68(30.9%)	220(100%)
Corpus N:	Obs.	12(10.3%)	88(75.9%)	16(13.8%)	116(100%)
	Exp.	31(26.7%)	48(41.4%)	37(31.9%)	116(100%)

The numbers of marginal and intervocalic interruptions in polysyllabic words are presented in Table III. The figures suggest a preference for intervocalic interruptions that precede consonants in both corpora. In order to evaluate whether this impression constitutes a statistically significant result, we need an estimation of the hypothetical pattern of results under the assumption of a random localization of interruptions. Starting from the IPA transcription of the words, the quotient of the number of phoneme transitions in one of the three categories (marginal; intervocalic/consonant or intervocalic/vowel) and the total number of phoneme transitions was taken as a valid estimation of the expected probability of an interruption in that category. For example, the word "aardappel" (potato), pronounced /ardɑpəl/, contains six phoneme transitions. There are five intervocalic transitions, three of which (/a/-/r/; /r/-/d/; /ɑ/-/p/) involve a consonant on the right side. In the two remaining intervocalic transitions a vowel occurs on the right side (/d/-/ɑ/; /p/-/ə/). Thus, the odds that an interruption will "land" on an intervocalic location preceding a consonant are three out of six, or 0.50, against two out of six (0.33) for an intervocalic position preceding a vowel. Consequently, the expected likelihood of a marginal interruption is 1 minus (0.50 + 0.33), which equals 0.17.

The expected probabilities for all words were averaged to produce expected proportions for the total set. These proportions were multiplied by the total number of observations to obtain expected frequencies of the three types of interruption (Table III), which were tested against the observed frequencies by means of chi-square tests. The observed distributions of interruptions appear to significantly deviate from chance expectations in both corpus T ($\chi^2 = 16.35$, df $= 2$, $p < 0.001$) and corpus N ($\chi^2 = 28.48$, df $= 2$, $p < 0.0001$). The interruption type that contributes most to the obtained chi-square values is intervocalic/preconsonantal which sustains the impression that the results reflect a preference for this type of interruption.

A breakdown of interruption locations over fragmentation types in Fig. 2 reveals that marginal interruptions are most frequently associated with Rbs; intervocalic preconsonantal interruptions with WIPs; and intervocalic interruptions preceding a vowel with Rms. This distributional difference is significant for corpus T ($\chi^2 = 247.76$, df $= 4$, $p < 0.0001$). For corpus N, testing conditions were less than optimal, since four out of nine cells produced expected frequencies of less than 5 (Leach, 1979). Nevertheless, the test result ($\chi^2 = 91.37$, df $= 4$, $p < 0.0001$) can be considered to support the findings in corpus T.

In terms of the interruption–restart framework, these results imply that marginal interruptions, all of which occur word-initially, are followed by full retracing, i.e. restarting from the word beginning. Intervocalic interruptions that precede a vowel are generally followed by partial retracing. It appears that all of the partially retraced restarts in both corpora (with one exception in corpus T) begin with a consonant

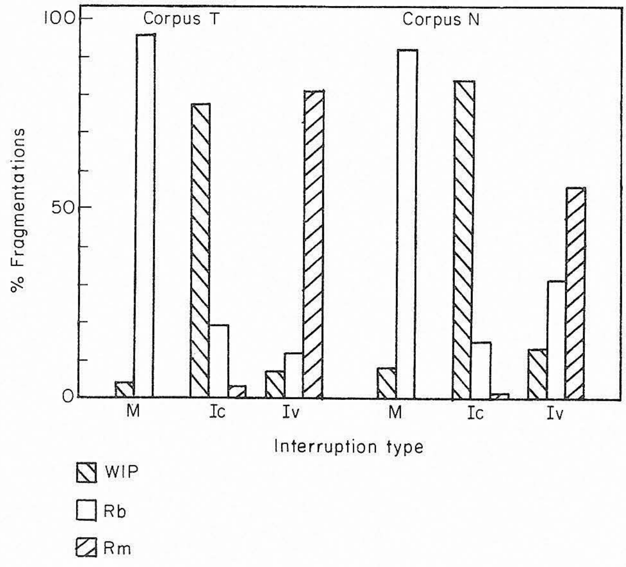

Figure 2. The percentages of word-internal pauses (WIP), repetitions of word beginnings (Rb) and word-medial repetitions (Rm) in polysyllabic words as a function of the type of interruption: marginal (M), intervocalic/before a consonant (Ic), or intervocalic/before a vowel (Iv).

that precedes the place of interruption (see examples 6 and 7). Intervocalic interruptions preceding consonants appear to be generally associated with immediate restarts, i.e. exactly from the point of interruption.

These interdependencies of interruption type and restarting (as indicated by fragmentation class) suggest an organization of speech in terms of CV(C) units. However, the interruptions *per se* agree only in part with the apparent CV(C) organization: 129 (58.6%) in corpus T and 88 (75.9%) in corpus N. Apparently, other factors also affect the position of interruptions. These will be discussed in the following sections.

3.2. *Factors affecting intervocalic interruptions*

Elicited syllabification studies suggest three variables that may affect the location of an interruption: (1) the manner of articulation of medial consonants; (2) (phonological) length of vowels; and (3) lexical stress. In the present data the role of each of these factors will be evaluated by comparing the proportions of interruptions preceding the medial consonant(s), as in examples 14–16, with the proportion of interruptions falling after or within medial consonants, as in examples 17–19.

(14) T023– 75 hɛ-pələ	(helpen/help)
(15) N031–180 poxə-tɑnt	(bovenkant/top side)
(16) N211–483 pɑ-kjə	(pakje/present)
(17) T205–110 ɛs-kimo	(eskimo)
(18) N242–156 ɔm-hox	(omhoog/upward)
(19) T102–231 pRanit-ɑuto	(brandweerauto/fire engine)

Figure 3 shows the proportion of interruptions falling just before the medial consonant(s) as a function of the quality of the (first) medial consonant. In both corpora,

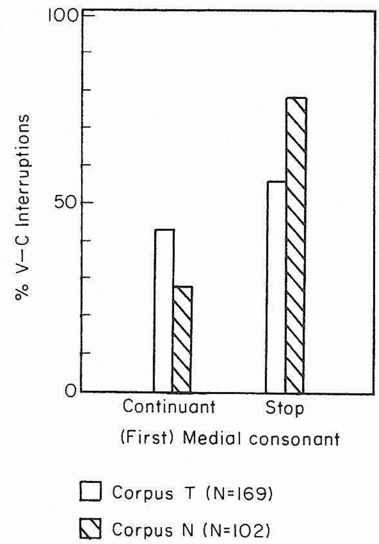

Figure 3. The percentages of interruptions between a vowel and the subsequent medial consonant as a function of the type of consonant (continuant *vs.* stop).

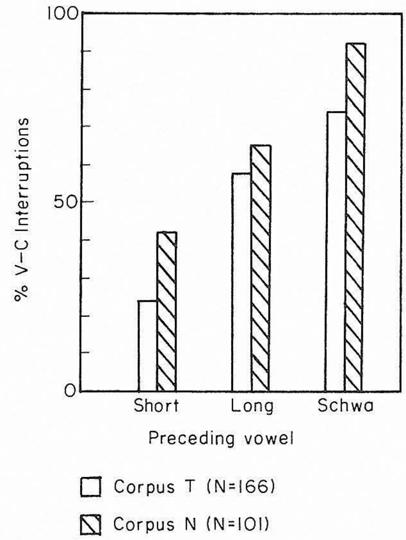

Figure 4. The percentages of interruptions between a vowel and the subsequent medial consonant as a function of the length of the vowel (short; long or diphthong; schwa).

this proportion is higher when the (first) medial consonant is a stop than when it is a continuant, indicating that stop consonants tend to be separated from the preceding vowel whereas continuants tend to "stick" to it. However, the difference reaches significance in corpus N only ($\chi^2 = 24.13$, df $= 1$, $p < 0.001$).

The effect of the quality of the preceding vowel on the place of interruption is shown in Fig. 4. The vowels are split up into three categories: (1) short (lax) vowels; (2) long (tense) vowels and diphthongs; and (3) the schwa. It appears that long vowels/diphthongs and schwas are more often associated with interruptions before medial consonants than are short vowels. This distributional difference reaches significance in both corpus T ($\chi^2 = 26.39$, df $= 2$, $p < 0.001$) and corpus N ($\chi^2 = 11.69$, df $= 2$, $p < 0.005$).

These findings bear a resemblance to the phonological observation that short vowels (in Dutch) have to occur in closed (CVC) syllables, whereas long vowels, diphthongs and schwas can also occur in open (CV) syllables (cf. van der Hulst, 1985). In this connection, it is interesting to have a look at the interruptions around syllable transitions that consist of a single consonant. In 56 cases (in both corpora) the medial consonant is preceded by a short vowel. In 25 of these (44.6%) the interruption occurs after the consonant. In 15 cases, the post-consonantal interruption is followed by a retraced restart which involves only the consonant directly preceding the interruption, as in (20). These cases constitute what could be called a behavioural analogue to ambisyllabicity. This "ambisyllabic" pattern is slightly less frequent in cases where a long vowel, diphthong of schwa precedes the medial consonant: 24 out of 110 interruptions (21.8%) are post-consonantal; 22 of these are followed by partially retraced restarts. So, the predominant interruption–restart pattern after a long vowel, diphthong or schwa corresponds to (21).

(20) T203– 70 plɑʃ+ʃə (plasje/piddle)
(21) N023–358 amna-xə (aanhangwagen/trailer)

Figure 5 shows the effect of lexical stress on the location of interruptions. Only those cases are included in which the vowel bearing primary stress is located either directly before or after the interruption. The results indicate that when lexical stress precedes the interruption, the medial consonants are less often separated from the preceding vowel than when stress follows the interruption. This effect is significant in corpus T only ($\chi^2 = 9.23$, df $= 1$, $p < 0.005$). The absence of a significant effect in corpus N is presumably due to the limited number of cases in which lexical stress followed the interruption (7). Nevertheless, the results from both corpora appear to agree in

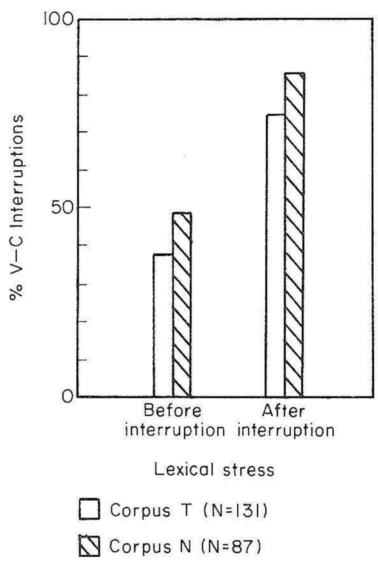

Figure 5. The percentages of interruptions between a vowel and the subsequent medial consonant as a function of the position of lexical stress: before the interruption *vs.* after the interruption.

supporting the conclusion that medial consonants tend to "stick" to stressed vowels. It should be noted that this tendency may be partially responsible for the high proportion of pre-consonantal interruptions after schwas since schwas typically are reduced non-stressed vowels.

3.3. *Effects of morphological structure*

In order to evaluate whether the morphological composition of words influences fragmentation, a criterion for morphological complexity is needed that is objectively related to the lexical inventory of the children. It was decided that a word could only be considered morphologically complex if at least one of its constituting morphemes occurred independently in the vocabulary up to the point in time when the (fragmented) compound was spotted. Of course, in the case of inflected or derived words this freely occurring part had to be the stem. This criterion implied that some words had to be considered simple at one point in time and compound at a later point if one of the constituting morphemes had appeared independently in the interval between the two occurrences.

According to our criterion 39.1% of the fragmented polysyllabic words in corpus T, and 58.6% in corpus N, are morphologically complex. These figures suggest that morphological complexity is not a major determining factor in fragmentation which appears to be sustained by the pattern of interruptions in morphologically complex words. Table IV indicates that the preference for morpheme preserving interruptions is slight. Furthermore, non-significant chi-square values seem to indicate that the distribution of interruptions over syllable preserving and distorting positions is not affected by the effect with respect to morphological boundaries.

Therefore, a better way to assess the influence of morphological structure seems to be to evaluate whether interruptions show a preference for syllable transitions that coincide with a morpheme boundary over syllable transitions that do not coincide with a morpheme boundary.

Table V summarizes the interruptions in polysyllabic polymorphemic words. To be able to test for a preference for morpheme boundaries, only words that had at least one morpheme boundary less than the number of syllable transitions were selected. To evaluate whether the proportions of morpheme-preserving interruptions exceeded chance values, expected proportions were computed. The expected probability of an interruption occurring at a morpheme boundary is equal to the quotient of the number of syllable transitions involving a morpheme boundary and the total number of syllable

TABLE IV. Distribution of morpheme preserving and -distorting interruptions over marginal, pre-consonantal and pre-vocalic positions

	Corpus T		Corpus N	
	morpheme distorting	morpheme preserving	morpheme distorting	morpheme preserving
marginal	8(20.0%)	2(4.3%)	4(14.3%)	1(2.5%)
pre-consonant	24(60.0%)	32(69.6%)	23(82.1%)	35(87.5%)
pre-vowel	8(20.0%)	12(26.1%)	1(3.6%)	4(10.0%)
Total	40(100%)	46(100%)	28(100%)	40(100%)

TABLE V. Distribution of interruptions over syllable transitions coinciding with morpheme boundaries and syllable transitions not coinciding with morpheme boundaries

	Corpus T	Corpus N
morpheme boundary	15(51.7%)	21(77.8%)
no morpheme boundary	14(48.3%)	6(22.2%)
Total	29(100%)	27(100%)

TABLE VI. Morpheme preserving and -distorting interruptions in bimorphemic affixed words *vs.* bimorphemic lexical compounds

	Corpus T		Corpus N	
	lexical compounds	affixed words	lexical compounds	affixed words
morpheme distorting	7(41.2%)	17(56.7%)	2(8.7%)	19(70.4%)
morpheme preserving	10(58.8%)	13(43.3%)	21(91.3%)	8(29.6%)
Total	17(100%)	30(100%)	23(100%)	27(100%)

transitions. For example, the word "unbelievable" contains four syllable transitions and two morpheme boundaries. Therefore, the expected probability that an interruption will fall on a syllable transition involving a morpheme boundary is 2/4, or 0.50.

The average expected proportions are 0.489 for corpus T, and 0.478 for corpus N. The observed proportion in corpus T does not significantly deviate from chance in a binomial test. For corpus N, on the other hand, a significant result ($p < 0.005$) was obtained which seems to indicate a preference for interrupting at syllable transitions that coincide with morpheme boundaries. Furthermore, Table VI suggests that lexical morpheme boundaries are more often preserved than stem-affix boundaries in corpus N ($X^2 = 16.94$, df $= 1$, $p < 0.001$). This effect did not occur in corpus T (see Table VI). Thus, although the number of relevant observations is small the overall pattern of results seems to underscore the rather limited role of morphological structure in interrupting.

To conclude this section, the relation between morphological structure and *restarting* will be briefly considered. It is clear that all repetitions of word beginnings (Rb) involve retracing to a morpheme boundary, namely the word onset. Furthermore, in word-internal pauses, only those that involve morpheme preserving interruptions also involve restarting on morpheme boundaries, by definition. Of the 53 WIPs in polymorphemic words in corpus T, 33 (62.3%) are morpheme preserving and thus incorporate a (non-retraced) restart at a morpheme boundary. In corpus N, this number is 34 out of 53 (64.2%). Of the word-medial repetitions (Rms), 20 occurred in polymorphemic words in corpus T, of which 13 (65%) involve retracing to a morpheme boundary. In corpus N, 1 of the 4 Rms in polymorphemic words involves retracing to a morpheme boundary.

TABLE VII. The distribution of interruptions over different positions in CVC monosyllables

	Location of interruption				
	In onset cluster	Between onset & vowel	Between vowel & final cons.	In final cluster	Total
Corpus T	8(10.1%)	43(54.4%)	27(34.2%)	1(1.3%)	79(100%)
Corpus N	-(-)	29(61.7%)	16(34. %)	2(4.3%)	47(100%)

3.4. *Syllable-distorting interruptions*

Of all 363 fragmentations (excluding repetitions of word endings) in corpus T, 191 (52.6%) distort the syllable structure of words; 48 (13.2%) involve "marginal" interruptions in polysyllabic words, 143 (39.4%) interrupt monosyllabic words. In corpus N fragmentations involving syllable distorting interruptions amount to 72 (40.9%). Twelve (6.8%) consist of "marginal" interruptions in polysyllabic words, 60 (34.1%) interrupt monosyllables. The distribution of interruption locations in CVC monosyllables is shown in Table VII. Few interruptions occur in initial or final clusters. The majority falls either between onset and vowel or between vowel and final consonant (cluster). Of these two the pre-vocalic position is preferred over the post-vocalic position, as indicated by a binomial test ($p = 0.05$, one-tailed) in both corpora. This result suggests that the vocalic core of monosyllables is more tightly attached to the final consonants than to the initial consonants. Similar proposals have been derived from both phonological analyses (e.g. Fudge, 1969) and experimental data (Treiman, 1985).

4. Discussion

Spontaneous word fragmentations appear to show some fairly systematic features. Monosyllabic words are almost always fully restarted after an interruption. In polysyllabic words, most interruptions occur just before intervocalic consonants. In these cases, the interruption is followed by an immediate restart. If an interruption occurs somewhere else in the word, restarting usually involves retracing, either to the medial consonant that directly precedes the place of interruption (if there is one) or to the word onset. The role of morphemes is relatively limited. There is an inclination to fully restore words, and in corpus N a preference for interrupting on syllable transitions that coincide with morpheme boundaries in lexical compounds was found. In summary the results seem to support the hypothesis that speech production, on the level of execution, is organized primarily in syllable sized units. These units appear to preferably assume CV(C) shapes. This agrees with speculations concerning the "canonical" or "archetypical" nature of the CV syllable (Collier & De Schutter, 1985).

Case studies invariably evoke the problem of generalizability. In this connection it is useful to recall that N and T differed quite a lot in rate and stage of language development. Moreover, they showed a considerable difference in articulatory maturity. Despite these differences the pattern of results appears to be essentially the same in both children. Consequently, we feel that the results can be considered representative for a larger population. The question that remains is whether the results agree with those of related studies.

It appears that the results of this study and those of elicited syllabification experiments show some notable resemblances. The experimental studies indicated that stressed syllables tend to "attract" consonants (Fallows, 1981). Moreover, long vowels are more often separated from the subsequent consonants than short vowels (Collier & De Schutter, 1985), and stop consonants are more often separated from the preceding vowel than continuants (van den Broecke & Westers, 1986). Each of these effects recurred in the present data. These correspondences suggest that elicited syllabifications, just like spontaneous fragmentations, primarily reflect characteristics of the execution level of speech production. One finding that supports this conclusion is the tendency to interrupt *before* stop consonants and *after* continuants which seems to be related to the amount of stricture in the articulatory channel. Stated simply: stops are "ideal" places for interruption because of the total articulatory closure (cf. van den Broecke & Westers, 1986).

This study has also provided some results that are analogous to phonological analyses of syllabification in Dutch. In particular the proposal that short vowels have to be "checked" by a consonant and its consequence that single medial consonants following short vowels are linked to both the preceding and the following syllable (cf. van der Hulst, 1985) has a parallel in the present results. Maddieson (1985) has argued that the association between short vowels and closed syllables reflects a universal characteristic of speech production, which is "phonologized" in some languages (e.g. Dutch). The correspondence between the articulatory data of this study and the phonological analysis of Dutch syllabification seems to be in agreement with Maddieson's hypothesis.

The results of this study are compatible with previous findings that point at the predominant role of the syllable in the development of speech (Ingram, 1978). Recently, Kent & Bauer (1985) have argued that the CV syllable "can be likened to discrete motor patterns that ethologists have called by names such as 'fixed action patterns' (...) 'typical form' (...) 'fixed motor pattern' (...)" (p. 517). Apparently, syllables are the genetically given articulatory units that can be probed in both younger and older children. The manipulation of phoneme-sized units, either deliberate (fragmentation) or accidental (speech errors), which points at the functioning of phonetic representations over and above the articulatory level of processing, can only be witnessed in older children and adults. This seems to suggest that during the early stages of development the speech production mechanism only incorporates the "phylogenetically old" (cf. MacNeilage, 1985) articulatory level. The planning level apparently emerges later in development, presumably in response to the rapid growth of the vocabulary, which calls for an efficient rule-based interface between lexicon and articulatory apparatus.

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