Clinical Linguistics & Phonetics

The relation between prosodic structure, syllabification and segmental realization: Evidence from a child with fricative stopping

Shula Chiat

Published online: 09 Jul 2009.

Submit your article to this journal

Article views: 103

View related articles

The relation between prosodic structure, syllabification and segmental realization: evidence from a child with fricative stopping

SHULA CHIAT

Department of Clinical Communication Studies, City University, Northampton Square, London EC1V 0HB

Abstract

This study is concerned with the interaction between prosodic structure, phonotactic structure and syllabification in the realization of segmental targets. It is based on a detailed investigation into the realization of intervocalic fricative targets by a child who stopped fricatives word-initially, but produced them correctly word-finally. Intervocalic fricatives in different prosodic and phonotactic domains were elicited using controlled repetition tasks, backed up by speech samples. It was found that intervocalic fricatives were realized correctly provided they occurred between strong and weak syllables within a word, in a phonotactic sequence which is permissible word-finally, e.g. /f/ in *buffalo, selfish*. Intervocalic fricatives were generally stopped in other prosodic domains, e.g. /f/ in *beautiful*, and in other phonotactic domains, e.g. /f/ in *comfort*. These findings have implications for the processes involved in the output of lexical phonology.

Introduction

This paper is concerned with the psycholinguistic implications of children's phonological errors. It follows up previous observations about patterns of errors, delving into details of these patterns in order to explore further their significance for the child's phonological processing and hence for the structure of phonological processing in general. More specifically, it investigates the prosodic factors which determine the realization of a target phoneme, and draws inferences about the interaction between prosodic and segmental factors in speech production.

It has been widely observed that children's phonological substitutions may be sensitive to phonological context (e.g. Smith, 1973; Ingram, 1974): the articulation of a target phoneme may depend on its position relative to other phonemes, as in consonant harmony, initial voicing, final devoicing. However, there has been little interest in the nature of the phonological domain on which realization of the target phoneme depends. A single-case study of velar fronting (Chiat, 1983) indicated that the realization of the velar target depended on its position relative to the stressed vowel in the word. The child fronted /k/ and /g/ when these occurred word-initially (e.g. <u>come</u>) or before a stressed vowel within a word (e.g. for<u>get</u>), but produced them correctly word-finally (e.g. <u>make</u>) or preceding an unstressed vowel in a word (e.g. ti<u>ck</u>et). This general pattern was subject to a small number of lexical exceptions in

which initial velars were realized correctly, e.g. car. The observed effect of stress on the realization of the velar did not operate across word boundaries: in connected speech, unstressed function words with reduced vowels did not combine with neighbouring stressed syllables to affect velar production. This gave rise to contrasts between a word such as bacon, realized as [beɪkən], and a phrase such as they can, realized as [ðeɪ kən]. In contrast to production, the child's perception of the velar/alveolar distinction was perfect. On the basis of this pattern, it was argued that the error involved in fronting:

(1) occurred in output
(2) occurred in lexical units
(3) affected particular positions within the prosodic structure of these output lexical units.

This argument had certain implications for the structure of phonological processing. The first implication arises from the observation that a segmental feature such as place of articulation may be realized differently by the child in different prosodic domains. This suggested that a phoneme such as /k/ is not the category being processed at the point where fronting occurs (whether this is the lexical representation or the articulatory planning of that representation). Rather, segmental features are processed as parameters of a prosodic structure. These features-of-prosodic-structure constitute the category which is at stake in fronting.

The second implication arises from the finding that fronting occurred within word units, was subject to lexical exceptions, and was confined to output. This led to the postulation of a separate lexical representation for output (see Chiat, 1983 for further details). However, subsequent investigation (Brett, Chiat and Pilcher, 1987) suggested that fronting does not occur in the lexical representation. This study found that children who front velars in real words also do so in nonwords, which by definition are not lexically represented. It was also found that children who fronted in their production of velars nevertheless made a velar/alveolar distinction in a task which required them to judge whether a picture (e.g. a picture of a cap) began with /k/ or /t/. On the basis of this investigation, it was concluded that the child has a correct internal representation of the velar, and that fronting occurs after lexical access, at a stage when the articulation of words is being planned.

These studies left open various further questions about the stages and units of processing implicated in fronting and other phonological processes. In particular, what is it about certain domains which makes the child more or less able to approximate the articulatory target in that domain? What does this tell us about the relevant stage of output processing? In order to clarify what it is about certain domains that facilitates the production of a segment, we need to know more about what defines those domains.

In the above description, the pattern of velar fronting was specified in terms of position of the target relative to the stressed vowel in the word. Another way of describing this pattern is in terms of syllabic structure: velars are fronted when they occur syllable-initially, but are correct in syllable-final or ambisyllabic (i.e. final of one syllable and initial of the next) position. This would imply that the child is able to plan movement from a vowel to a velar closure, but not from a velar closure to a vowel. The two different descriptions, in terms of word stress and syllabification, are clearly interrelated. Whether an intervocalic consonant is ambisyllabic or not depends on its position relative to stress in the word. In the child studied, an intervocalic velar was

treated as ambisyllabic and was correct if it occurred between stressed and unstressed vowels.

This relation between prosodic structure of the word, syllabification of that word, and the child's realization of segments within the word, has not yet been fully charted. Words are not simply linear sequences of stressed and unstressed syllables. Metrical phonology has shown that the rhythmic or prosodic structure of words is hierarchical: syllables are organised into layers of strong-weak combinations (Liberman and Prince, 1977; Selkirk, 1984). In looking at a child's segmental substitutions, it is, therefore, not sufficient to determine whether the segmental substitution depends on position relative to a stressed or unstressed vowel. The segment must be considered in terms of its position in the prosodic structure of the word, which means looking at the relevant segment in a range of prosodic domains. This is the object of the present study.

The subject of this study is a child whose speech showed fronting and stopping processes, both of which conformed to the pattern observed in Chiat (1983) and described above. The aim was to investigate a wider range of word structures in order to clarify the effects of prosodic and segmental factors on the target. Stopping was selected for this further investigation for two reasons. First, the child stopped all members of the fricative class, which meant that the stopping process offered wide scope for exploring the precise distribution of stopped fricatives. Second, stops and fricatives are especially distinct from an acoustic point of view, which facilitated transcription and eliminated the possibility of 'misperceiving' the child's realization of a target segment. The distribution of stopped fricatives was investigated through controlled repetition of words and phrases, elicited word production, and spontaneous word production.

Method

Subject

The subject, Stephen, was aged 4; 7–4; 10 over the period of investigation. His development was normal in all respects apart from his phonology. He was referred for speech therapy, and had attended a 'fronting group' for one week prior to the study. He received no further therapy until the end of the study.

Procedure

Stephen was observed on six occasions, in his home. On each occasion, he was given a repetition task designed to investigate his realization of the fricative targets /f, v, s, z/ in particular domains. The stimuli in these tasks were either words or phrases, controlled for position of the target fricative relative to stress and syllable structure. The set of stimuli for each task, together with the results for that task, are presented below in the Data and Analysis section.

These repetition data were supplemented by a sample of output collected in a naturalistic play setting. The purpose was to obtain a sample of fricative targets which were not immediate repetitions of an auditory model. In these play sessions, Stephen was provided with a Playmobil doctor's set, various props from other Playmobil sets, and a set of plastic animals. In the course of free play Stephen spontaneously produced words containing target fricatives. The investigator intervened in two ways in order to elicit fricative targets in positions which Stephen did not attempt

spontaneously. First, certain objects (e.g. a toy buffalo) were provided because their phonological representation contained a target fricative; if Stephen did not recognize the object, he was told its name and later asked what it was. Second, names were given to the Playmobil people in order to elicit fricative targets in positions which could not be exemplified by names of concrete objects. In some cases, very odd names (e.g. Parsifal) had to be used to provide examples of the required phonological structure. Again, Stephen was told the name and later asked who the Playmobil person was. The range of spontaneous and elicited words is presented below, together with the repetition data.

It will be noted that many of the words and unusual names used in the repetition tasks would be unfamiliar to a four-year-old, and in effect represent nonwords for the child. These nonwords were introduced in order to investigate phonological domains for which insufficient examples of familiar words were available. It could be argued that use of nonwords cannot throw light on the child's spontaneous phonological processing. There are a number of reasons for rejecting this argument. First, prior investigation indicates that children show the same pattern of errors in nonwords as in words (Brett *et al.*, 1987). Second, it was soon evident that Stephen reproduced the phonology of unfamiliar words very reliably, with syllabic and segmental structure matching the target, apart from the segmental substitutions which characterized his spontaneous output. Third, many familiar words showed stopping (e.g. all the words with initial fricatives, which Stephen consistently stopped); conversely, fricatives in unfamiliar words were often correct (e.g. evident, ozone, morphine). As will be clear from the results, the effects of phonological domain on fricative targets were extremely consistent, and the use of unfamiliar words did not produce exceptions to these effects. There was therefore no indication that familiarity either facilitated or impaired Stephen's realization of fricatives.

All data were recorded on a Sony WM-D6C Professional stereo cassette-recorder, using a Sony ECM-144 microphone. The data were transcribed within a day of the recording session. The realization of target fricatives produced in the repetition tasks and in the spontaneous/elicited output was then scored as correct, stopped, or other. *Correct* realizations were those which corresponded to the target in manner and place of articulation; *stopped* realizations were homorganic stops, i.e. the stop closest in place of articulation to the target fricative; *other* realizations were those which replaced the target with a consonant other than a homorganic stop, or omitted it. Since Stephen produced words with correct syllabic and segmental structure there were no problems in identifying and classifying targets.

The scores for targets in different phonological domains were compared statistically using χ^2 analyses.

Data and analysis

1. Word stress, syllable boundaries and segmental realization

Stephen was presented with a repetition task designed to investigate the relation between word stress, syllable boundaries and the realization of fricatives. It consisted of words with target fricatives in each of the following domains:

(1) word-initial, before main stressed V e.g. sun, fat
(2) word-final, following main stressed V, e.g. miss, laugh

(3) intervocalic in two-syllable word, following unstressed V and before main stressed V, e.g. decide, before

(4) intervocalic in two-syllable word, following main stressed V and before unstressed V, e.g. person, over

(5) intervocalic in three-syllable word, following unstressed V and before secondary stressed V, e.g. exercise, interfere.

There were ten examples in each category. The 50 items were presented in random order. See Appendix 1a for the list of stimuli. The results are presented in Table 1a. The scores in each category were analyzed using a Sign test; in all cases, $p < 0.005$ (one-tailed).

A list of words produced in the sample of spontaneous/elicited data is presented in Appendix 1b. These included words with target fricatives in the categories word-initial, word-final, and intervocalic following main stressed V. The scores for all word tokens in each of these categories are shown in Table 1b. A χ^2 analysis indicated a significant difference between the final and intervocalic fricatives, on the one hand, and the initial fricatives, on the other ($\chi^2 = 185.55$, df $= 1$, $p < 0.001$).

It is clear from both the repetition and the spontaneous/elicited data that Stephen's stopping of fricatives fits the pattern previously observed for fronting (see Introduction). He stops fricatives in syllable-initial position, and produces them correctly in syllable-final position. Intervocalic fricatives are ambisyllabic and therefore are correctly articulated if they follow the stressed vowel, but not elsewhere.

Table 1a. Repetition of fricative targets controlled for position relative to word boundaries and word stress.

	Correct	Stopped	Other
Initial	0	10	0
Second syllable, stressed	0	10	0
Second syllable, unstressed	10	0	0
Third syllable, secondary stress	0	9	1
Final	10	0	0

Table 1b. Spontaneous/elicited production of fricative targets in word-initial, word-medial, and word-final positions.

	Correct	Stopped
Initial	6	78
Second syllable, unstressed	37	5
Final	109	0

2. Word boundaries, phrasal stress, and segmental realization

Stephen was presented with a repetition task designed to investigate the effect of word boundaries and phrasal stress on the realization of fricatives, for comparison with the effects of syllable boundaries and word stress. This meant looking at the realization of fricative targets which occur intervocalically *within a phrase*, but at a word boundary within that phrase, and comparing this with the realization of fricative targets which

occur intervocalically *within a word* (stress being kept constant). The stimuli consisted of three- to five-word constructions, where one word ended in a fricative and the following word began with a vowel. Three construction types were used, with ten examples of each type:

(1) unstressed auxiliary + stressed pronoun, e.g. Where have 'I been; Has 'he gone
(2) unstressed copula + stressed adjective/stressed preposition, e.g. The mum is 'old; The light is 'on
(3) stressed auxiliary + unstressed pronoun, e.g. Where 'have I been; 'Has he gone.

The thirty items were presented in random order. See Appendix 2 for the list of stimuli. The results are presented in Table 2.

It was not necessary to analyse these data statistically since they are clear-cut: in no case did Stephen stop the target fricative. In two of the construction types, he reproduced the fricative perfectly. In the construction unstressed auxiliary + stressed pronoun, he deviated from the target, but not by stopping the fricative: his errors involved switching the stress pattern to stressed auxiliary + unstressed pronoun (two cases), omitting the final fricative (one case), and replacing 'where have' with unintelligible [ɛfən] once.

It is clear that word-final fricatives are realized correctly in connected speech even when they occur intervocalically and prior to stress. The word boundary blocks the stopping of the fricative which would occur in a single word with the same phonetic properties. That is, Stephen produces the fricative correctly in is 'odd, but stops it in a similar phonetic context such as de'cide. It may be concluded that the fricative is syllable-initial within the single word decide, but is syllable-final within the phrase is odd; where there is a word boundary, stopping does not treat an intervocalic fricative as syllable-initial in relation to the following vowel. Spontaneous data reinforce this conclusion. Word-final fricatives were preserved, even when they followed an unstressed vowel and preceded a stressed vowel as in his eye, his arm.

This finding again concurs with the earlier finding in the case study of fronting (see Introduction). The effect of stress on syllabification and the realization of the segment again operates within words, and not across word boundaries.

The stopping observed in the data and analysis so far indicates that the stopping process affects fricatives according to their position within the word relative to syllable boundaries, and that this in turn depends on word stress. In particular, fricatives which occur intervocalically within the word are only stopped if they precede stress; they are realized correctly where they follow stress and presumably are ambisyllabic.

Table 2. *Repetition of target fricatives controlled for position relative to word boundaries and phrasal stress.*

	Correct	Stopped	Other
Unstressed–stressed			
Auxiliary 'pronoun	6	0	4
Copula 'adjective/'preposition	10	0	0
Stressed–unstressed			
'Auxiliary–pronoun	10	0	0

However, these data do not fully define 'ambisyllabic'. Only three intervocalic positions have been considered: stressed V–unstressed V, unstressed V–stressed V, stressed V–unstressed V–secondary stressed V. Further data are required to determine how Stephen treats intervocalic fricatives which occur at other points in the prosodic structure of the word. The following investigation seeks to clarify which intervocalic consonants are ambisyllabic by probing further into the effects of prosodic position on the realization of fricatives.

3. Prosodic structure, syllabification and segments

Stephen was presented with a repetition task designed to investigate whether an intervocalic fricative is ambisyllabic between unstressed vowels, and between main stressed and secondary stressed vowels, within a word. The stimuli included words with target fricatives in the following categories:

(1) between initial stressed V and unstressed V of three-syllable word, e.g. possible, difficult

(2) between unstressed V and unstressed V of three-syllable word, e.g. opposite, beautiful

(3) between main stressed V and secondary stressed V of two-syllable word, e.g. missile, perfume.

There were twenty examples within each category which were presented together in random order. See Appendix 3a for the list of stimuli. The results are presented in Table 3a.

A χ^2 analysis indicated that in three-syllable words, intervocalic fricatives between the initial stressed and second unstressed vowels were significantly different from those between the second unstressed and third unstressed vowels ($\chi^2 = 12.133$, df $= 2$, $p < 0.005$). However, intervocalic fricatives between main stressed and secondary stressed vowels were not significantly different from either of the other two categories. For initial stressed–unstressed *vs.* initial stressed–secondary stressed, $\chi^2 = 5.36$, df $= 2$, $p < 0.1$. For unstressed–unstressed *vs.* initial stressed–secondary stressed, $\chi^2 = 2.032$, df $= 2$, not significant.

The sample of spontaneous/elicited output provided examples of three-syllable words with target fricatives in different prosodic positions. The data are presented in Table 3b.

For a list of the word types in each of these categories, see Appendix 3b. A χ^2 analysis of these data replicated the analysis of the repetition data: fricative targets between initial stressed and unstressed vowels were significantly different from fricative targets between unstressed and unstressed vowels ($\chi^2 = 58.655$, df $= 1$, $p < 0.001$).

Table 3a.   *Repetition of target fricatives controlled for position in prosodic structure of the word.*

	Correct	Stopped	Other
Between stressed V and unstressed V	16	3	1
Between unstressed V and unstressed V	5	11	4
Between stressed V and secondary stressed V	9	7	4

Table 3b.   Spontaneous/elicited production of fricative targets in different prosodic positions in the word.

	Correct	Stopped
Between stressed V and unstressed V	38	0
Between unstressed V and unstressed V	7	41

It emerges that Stephen generally produces fricatives correctly between the stressed and unstressed vowels of a word, such as the /f/ in difficult, but generally stops fricatives between the unstressed vowels of a word, such as the /f/ in beautiful. Fricatives between main stressed and secondary stressed vowels (in a word such as perfume) vary in their realization, falling between these other two categories, and not differing significantly from either.

It may be concluded that the realization of fricatives does not depend simply on position relative to stressed vowels. Rather, it depends on position within the entire prosodic structure of the word. An intervocalic fricative is most likely to be ambisyllabic and correct if it follows a stressed vowel and precedes an unstressed one; it is less likely to be ambisyllabic and correct if it precedes a secondary stressed vowel, though not significantly less; and it is least likely to be ambisyllabic and correct if it follows an unstressed vowel and precedes an unstressed vowel. This suggests that syllabification and prosodic structure are integrally related. More specifically, two consecutive syllables may form a unit containing an ambisyllabic consonant, depending on the relative stress of those syllables: a stressed and following unstressed syllable form such a unit; an unstressed and stressed syllable, or unstressed and unstressed syllable do not; a stressed and secondary stressed syllable may.

Stephen's strength in producing fricatives in ambisyllabic position is especially well illustrated by his handling of words which contain an ambisyllabic or final stop and a syllable-initial fricative, as in medicine, opposite. Stephen most often transposed these consonants: he realized medicine consistently as [mɛsɪdɔ̃ʔ] and opposite as [ɒsəbɪt] or [ɒpɪdɪs] or [ɒpstɔɪʔ]. In words containing fricatives in both prosodic positions, e.g. Davison, Parsifal, the ambisyllabic fricative was always correct, whereas the syllable-initial one was usually stopped, to give [deɪvɪdən] or [deɪsɪdən], and [pɑsəbəl]. Thus, Stephen adapted these words to fit the phonotactic (syllabic plus segmental) structure he was able to produce.

A closer look at the exceptions in the repetition and spontaneous/elicited data presented in this section suggested that these were not accidental. Out of 110 targets which occurred intervocalically between stressed and unstressed vowels, 101 (92%) were correct. Six of the nine exceptions were labio–dental targets /f, v/ which followed a stop or nasal consonant, as in breakfast, invalid, envious. The sequence stop + /f, v/ and the sequence nasal + /f, v/ have something in common: they do not occur word-finally in English. This means that they cannot be an ambisyllabic cluster when they occur intervocalically; the first consonant (stop or nasal) is ambisyllabic, but the following fricative must be the initial of the next syllable. As a syllable-initial fricative, it is stopped. In contrast, Stephen produced fricatives correctly in intervocalic sequences which are permissible in word-final position. For example, the sequences of nasal + /s/ and stop + /s/ may occur word-finally and may therefore be ambisyllabic clusters; Stephen produced the alveolar fricative correctly in these sequences when

they occurred intervocalically, in words such as <u>answer</u>, <u>pencil</u>, <u>accident</u>. It appeared from these limited data that the phonotactic possibilities of English were a further factor in Stephen's realization of fricatives. It was therefore hypothesized that even where the stress pattern is such that two syllables form a prosodic unit, an intervocalic consonant can only be ambisyllabic if it is one which can occur as a word-final consonant. The following repetition task was designed to test this hypothesis.

4. Phonotactic structure, syllabification, and segments

Stephen was presented with a repetition task designed to investigate the effect of phonotactic possibilities on the realization of intervocalic fricatives. The stimuli included ten words with intervocalic liquid + labio–dental fricative, a sequence which can occur word-finally; and ten words with intervocalic stop/nasal/fricative + labio–dental fricative, which cannot occur word-finally. See Appendix 4a for a list of the stimuli.

The twenty words were randomized. The task was administered on two occasions, two weeks apart, in order to generate adequate numbers for statistical analysis. Data from the two presentations were pooled. The results for this task are presented in Table 4a.

A χ^2 analysis indicated that target fricatives which followed a liquid were produced significantly better than those which followed a nasal, stop or fricative ($\chi^2 = 15 \cdot 172$, df $= 2$, $p < 0 \cdot 001$). Stephen produced /-lf-/ and /-lv-/ perfectly, whereas he generally stopped /f, v/ following other consonants.

The sample of spontaneous/elicited data provided examples of fricatives in these categories. A list of the word types produced is presented in Appendix 4b. Table 4b shows the number of tokens which were correct and stopped for each category.

A χ^2 analysis again indicated a significant difference between target fricatives which followed a liquid and those which followed a stop or nasal ($\chi^2 = 5 \cdot 622$, df $= 1$, $p < 0 \cdot 025$).

By the time these data were collected, Stephen was beginning to produce fricatives correctly in positions where he had previously stopped them, so the significance of these results is particularly striking. It may be concluded that, within a given prosodic structure, phonotactic possibilities affect syllabification and the realization of seg-

Table 4a. *Repetition of intervocalic fricative targets in different phonotactic combinations.*

	Correct	Stopped	Other
Post-liquid	20	0	0
Post-nasal/stop/fricative	9	9	2

Table 4b. *Spontaneous/elicited production of fricative targets in different phonotactic combinations.*

	Correct	Stopped
Post-liquid	9	2
Post-nasal/stop	11	21

ments. An intervocalic fricative is ambisyllabic for Stephen only if it occurs in the prosodic structure strong-weak, *and* in a phonotactic sequence which can be word-final.

Neither prosodic factors nor phonotactic factors alone account for the pattern of stopping. The data in Section 3 indicated that intervocalic fricatives which meet the phonotactic criterion for ambisyllabicity but not the prosodic criterion are stopped, as in beautiful, elephant. Intervocalic fricatives which meet the prosodic criterion but not the phonotactic criterion are stopped, as in anvil, comfort, spiteful. Only intervocalic fricatives which meet both criteria are ambisyllabic and therefore correct, as in silver, skillful.

Discussion

This study sets out to clarify the factors which affect the realization of fricative targets in a child who stops fricatives selectively, and to make inferences about the psycholinguistic processing involved. The following discussion will first consider the structures implicated in Stephen's stopping: the nature of the unit over which stopping operates and the nature of the unit which stopping affects. The stage of processing which is at stake will then be considered. Finally, the implications for the structure of phonological processing will be discussed.

Structures implicated in stopping

Investigation into the domains in which Stephen stopped fricatives revealed that stopping was dependent on the prosodic and phonotactic structure of the word, which is integrally related to the syllabification of the word. Fricatives were stopped in the following domains:

(1) word-initial
(2) word-medial, following an unstressed vowel and preceding the main stressed vowel (between weak and strong syllables)
(3) word-medial, following the main stressed vowel and unstressed vowel (following strong plus weak syllables)
(4) word-medial, following a consonant with which it does not occur as a word-final cluster.

Fricatives were correct in the following domains:

(1) word-final
(2) word-medial, following the main stressed vowel and preceding an unstressed vowel (between strong and weak syllables).

There was vacillation in the realization of fricatives which followed the main stressed vowel and preceded a secondary stressed vowel.

This distribution of stopped and correct fricatives can be characterised more simply in terms of syllabification. Syllable-initial fricatives are stopped, while syllable-final and ambisyllabic fricatives are correct. A fricative is ambisyllabic if it occurs in the prosodic structure strong–weak, unless it follows a consonant with which it cannot combine to form a permissible cluster. On this description, it is unsurprising that Stephen vacillates in words which consist of two strong syllables and where the

first carries the main stress, since this prosodic pattern falls between the two prosodic patterns identified in the above description. On the one hand, the relationship between the two syllables is strong–weak, which is the prosodic context of an ambisyllabic fricative; on the other hand, the weak syllable is stressed, containing a full vowel, which distinguishes it from the prosodic context of an ambisyllabic fricative.

The maximum domain for prosodic and phonotactic effects on stopping appears to be the word. Prosodic and phonotactic factors beyond the word do not affect the realization of fricative targets. Fricatives which are intervocalic in the phrase, but at word boundaries, as in his eye, remain syllable-final or syllable-initial within the word, whatever the prosodic structure of the phrase. This applies to unstressed function words such as auxiliaries and possessive determiners, where the final fricative is treated as syllable-final rather than syllable-initial, so that the /z/ in his eye is realized as a fricative, rather than being stopped as it would be within a word such as deserve. This indicates that function words are independent prosodic units even when they are unstressed. It could be, however, that the morpheme rather than the word is the relevant unit. The current study did not investigate the effects of morpheme boundaries. The test case would be the realization of morpheme-final fricatives which are intervocalic within a word. For example, what would happen to the final /s, z/ of a root morpheme such as palace when a plural inflection is attached, and the morpheme-final /s/ becomes intervocalic? Where it is word-final, Stephen would produce the /s/ correctly, but with the plural inflection in palaces, that word-final /s/ turns up in an intervocalic position which Stephen usually stops. As yet, we have no evidence to indicate whether words or morphemes are the units within which the relevant prosodic and phonotactic structure is specified.

This description of the structures implicated in Stephen's stopping accords well with the structures posited by current theories in metrical phonology. In particular, the prosodic domain in which intervocalic consonants are ambisyllabic is similar (though not identical) to the foot unit in Selkirk's analysis of metrical structure (Selkirk, 1980). The foot is a metrical unit intermediate between the syllable and the word, consisting of either a single, strong syllable, or a strong syllable plus weak syllable. The justification for positing this prosodic category 'foot' was that it facilitated the description of stress patterns, and defined the relevant domain of certain phonological rules. The data from Stephen suggest that the foot is the prosodic domain to which stopping applies: foot-initial fricatives are stopped, while other fricatives (foot-medial and foot-final) are correct. In Selkirk's analysis, words containing two strong syllables, such as missile, consist of two feet. Stephen showed inconsistency in the realisation of medial fricatives in such words, implying some uncertainty as to whether the two syllables constitute a single foot or two feet. Within her more recent work, Selkirk (1984) reanalyses different types of metrical unit, including the foot, as different levels of metrical structure. In terms of this re-analysis, the first level above the syllable would be the metrical structure on which Stephen's stopping is specified. (See Black and Byng, 1986, for some discussion of the relevance of metrical phonology to psycholinguistics.)

From this description, it may be concluded that Stephen's stopping involves the processing of a prosodically specified segmental feature. The feature 'fricative' is processed differently according to whether it is syllable-initial or syllable-final/ambisyllabic, which in turn depends on its position within a prosodic and phonotactic structure. This relation of segmental features to prosodic and phonotac-

tic structure could be viewed from the opposite perspective: the difference in the processing of segmental features determines whether they are syllable-initial or syllable-final/ambisyllabic, and hence determines the prosodic structure of the word. It would appear that phonotactic structure, prosodic structure, syllabification, and segmental features are mutually dependent aspects of the word. Segmental features are parameters of prosodic structures, and prosodic structures are constituted by segmental features.

Stage of processing

In this section, I shall consider evidence bearing on the point, in input or output phonology, at which stopping occurs.

1. Input processing and internal representation of lexical phonology

We have no direct evidence concerning Stephen's perception of the fricative/stop distinction, since no input tasks were carried out. There was no investigation into Stephen's ability to make same–different judgements or to distinguish minimal pairs. However, there is ample evidence in the child phonology literature that children with phonological processes such as fronting and stopping have no problem distinguishing in input those features which they are failing to distinguish in output (Smith, 1973; Chiat, 1983; Brett *et al.*, 1987).

Furthermore, there is some evidence from spectrographic analysis of children's output that they are making a distinction between targets, even though this distinction is inaudible to the adult (Kornfeld, 1971). There is also evidence that children are able to make the distinction between targets internally when they retrieve the phonological representation of the word. Brett *et al.* (1987) found that children who fronted velars were nevertheless able to distinguish alveolars and velars when they were asked to classify pictures of items whose names began with /t/ or /k/. Hughes (1983) provides evidence of intact internal representations in phonologically disordered children. She shows that the children distinguish allomorphs of the plural morpheme which vary according to the word-final consonant they follow; this implies that the children have an internal representation of the word-final consonant even though they fail to produce it correctly. The children in these studies must have perceived and stored a distinction between the targets which they apparently fail to distinguish in their output. However, this is not necessarily the same distinction as the adult's. The possibility remains that these children make a distinction in input and output, but a non-adult one. If this is the case, the wide-ranging evidence that children are able to recognise the distinction in input is of limited significance: this success in perception does not rule out the possibility that the child is processing input differently from the adult. The child may be succeeding on the basis of a non-adult perceptual distinction, which in turn gives rise to a non-adult target in output. This remains a possible source of output errors for children who have been claimed to have intact perception, and for the child in the present study.

However, this study provides three pieces of indirect evidence that the error does not occur in input. First, the patterns of errors observed here and in Chiat (1983) are such that the errors occur in those positions which are most perceptually salient, i.e. initial of stressed syllables. It is unlikely that a fricative would be perceived as closer to a stop in stressed than in unstressed positions. More generally, it seems implausible

that Stephen would perceive the same categorical distinction as the adult in those positions which are least salient, and a different categorical distinction from the adult in more salient positions. Furthermore, certain of the production differences observed occur in contexts which are unlikely to differ acoustically or perceptually, e.g. awful (where /f/ is correct) *vs.* beautiful (where /f/ is stopped).

Second, there is evidence that Stephen has perceived a fricative even where he fails to produce it, in examples where he transposes a stop and a fricative, e.g. medicine realized as [mɛsɪdɔ̃ʔ], opposite as [ɒsəbɪt]. There is reason to think that Stephen has perceived both the stop and the fricative, and their sequence. Since he does not make errors of transposition in general, it is unlikely that he is misperceiving the sequence of consonants in these particular words. Since he does not replace stops with fricatives in any other context, it is unlikely that he is misperceiving the stop as a fricative. But if he has perceived the stop and the fricative and their sequence correctly, the transposition must occur somewhere other than in input.

Third, Stephen produces many phonologically complex sequences correctly, e.g. hospital, accident. It is unlikely that he would perceive certain complex sequences in the same way as an adult, while other less complex sequences are perceived differently from the adult.

If stopping does not occur in perception, might it occur in the internal representations which are derived from perception? The data in this study included many words which would be unfamiliar to Stephen, and could not possibly be in his internal lexicon. In line with previous evidence (Brett *et al.*, 1987), Stephen showed the same pattern of stopping in familiar and unfamiliar words. This suggests that stopping occurs in a process common to lexical and nonlexical production, and does not therefore involve lexical representations or the accessing of these.

2. Output processing

If Stephen perceives, stores, and accesses fricatives in an adult way, as I have argued, the stopping of fricatives must arise at a relatively late stage of output processing.

The stage of motor execution can be ruled out. There is widespread evidence of substitution processes in children which are not due to motor limitations. The best known example is perhaps the 'puzzle phenomenon' reported by Smith (1973), where the child realized puddle as [pʌgəl], but produced that very target ([pʌdəl]) for the word puzzle. There is similar evidence in Stephen's data that he is able to make the motor movements required to realize a target fricative which he stops. The effect of word boundaries on the realization of fricatives in similar phonetic contexts indicates that purely physical constraints are not responsible for stopping. The motor movements required to produce an intervocalic fricative within a word such as decide and a phrase such as his eye are the same, yet Stephen stops the first and produces the second correctly.

On the basis of the above arguments and evidence, it would seem that stopping occurs at a stage of articulatory or motor planning, at a point when lexical representations have been accessed, and are being programmed for motor execution. The structures involved in the stopping process provide some insight into this stage of articulatory planning. In the preceding section of the discussion, it was concluded that stopping affects a segmental feature as a parameter of a prosodic structure: Stephen's realization of fricative targets depends on whether they are syllable-initial or syllable-final/ambisyllabic, which in turn depends on their position in the arrangement of

strong and weak syllables within the word. The implications for articulatory programming are that Stephen is able to plan a fricative manner of articulation as a movement which closes the vocal tract from a vowel configuration, and that this is the movement involved in foot-final and foot-medial positions; he is unable to plan a fricative manner of articulation as a movement which opens the vocal tract towards a vowel configuration, and this is the movement involved in foot-initial position.

It was also observed that syllabification within a prosodic structure is affected by phonotactic possibilities within a word: Stephen's realization of an intervocalic fricative depends on whether it occurs in a phonotactic position which could be word-final. This suggests that a fricative manner of articulation can only be planned as a movement closing a strong syllable within a word if it has been experienced as a movement closing an entire word.

Taken together, these findings imply that speech is not programmed as a sequence of segments, consisting of movements from one tongue configuration defined by manner/place to another such configuration. Rather, speech planning is the planning of movements on a rhythmic unit, and the movements are planned differently depending on their position within that rhythmic unit. Under this interpretation, segmental placements are an abstraction of certain parameters from this continuous rhythmically based movement.

This view of articulatory planning accords with the action theory view of speech production (Fowler, Rubin, Remez and Turvey, 1980). The following quotation summarizes the relevant points:

> "There are regularities to which all utterances and all parts of all utterances conform. These include the special mode of breathing, the phonation mode of laryngeal adjustment ..., suprasegmental timing constraints, the near alternation of consonants and vowels and, in English, the near alternation of stressed and unstressed syllables. These regularities provide an organisational frame (of the musculature ...) for an utterance that both establishes the *possibility* of producing segments, and constrains the ways in which particular segments can be idiosyncratic. Viewed in this way, the idiosyncratic aspects of an utterance—that is, the distinctive features of its successive segments—are parametric values *of* an extant organisation; they are not substantives in themselves." (Fowler *et al.* 1980, p. 386).

This theory of speech production points up the interdependence between segmental and suprasegmental aspects of speech production which is implied by the analysis in this study. Such a theory contrasts with one in which segmental and suprasegmental aspects of speech are treated as separate aspects which are programmed independently even though they may interact.

It was noted in this study that the maximum domain of stopping was the word (though current evidence did not rule out the possibility that the morpheme is the relevant domain). Prosodic structure above the word level did not affect stopping; function words, even if unstressed, were treated as independent prosodic units. This suggests that the process of articulatory planning which we have posited is carried out for each word, independently of other words, in the output of phrasal syntax and prosody.

Further questions

This study identifies a particular relation between prosodic structure, syllabification, and segmental features in the articulatory processing of one child. Although this has

certain implications for articulatory planning mechanisms, it is important to recognize particular limitations of the data and hence of their implications. These limitations raise questions which require further investigation.

First, it may be that the prosodic, phonotactic, and phonetic features of English give rise to the particular interaction between these features which we have observed. There is evidence that children's acquisition of a segmental category is affected by its frequency in the input language (Ingram, 1986; Topbas, 1988). It is likely that the phonotactic structure of the syllable in other languages would also affect syllabification of larger units, which would in turn affect the realization of intervocalic consonants. For example, German allows syllable-final nasal + fricative: one might therefore expect that a German child with Stephen's pattern of stopping would treat intervocalic nasal + fricative as ambisyllabic, and produce the fricative correctly, unlike Stephen who treats the fricative as syllable-initial and stops it. It could also be that in languages with very different prosodic properties from English, the effects of prosodic structure on segmental realization would be different or non-existent. A syllable-timed language such as French realizes the strong–weak alternation very differently from English; weak syllables, for example, do not show vowel reduction. It would be interesting to know whether 'phonological processes' such as stopping and fronting are sensitive to prosodic structure in French, and if so, how they are affected. However, whatever findings emerge from cross-linguistic investigations, we would still have to account for the pattern observed in English, and such an account would still have implications for the general properties of the articulatory planning mechanism.

A second limitation of this study is that the particular relation between prosodic structure, phonotactic structure, and segmental realization has only been observed for one child, and for one phonological process. There is ample evidence that children who make particular substitutions do so with varying consistency. Some children who stop will do so in all contexts, while others will stop in selective contexts. Children who share Stephen's pattern of stopping, with a difference between syllable-initial and syllable-final, will not necessarily show exactly the same effects of prosodic and phonotactic structure. For example, other children may treat fricatives between unstressed syllables (e.g. the /f/ in beautiful) as ambisyllabic, and realize them correctly, unlike Stephen, who generally stops fricatives in this position. This would imply some flexibility in the way that segmental features are syllabified and hence in the way that they are programmed as parameters of prosodic structure.

Similarly, it may be that phonological processes involving segmental distinctions other than stop *vs.* fricative would show a different interaction with prosodic structure. For example, fronting, which involves the alveolar–velar distinction, may occur in a different set of domains from stopping; it may be that a child with syllable-initial fronting would treat the intervocalic velars between unstressed syllables as ambisyllabic, and realize them correctly. Preliminary exploration has suggested that this is indeed the case: that children who front in syllable-initial position do not do so in words such as Africa, elegant. This might imply that different types of movement (e.g. closure as opposed to partial closure) are planned differently as parameters of prosodic structure. In this case, syllabification and segmental distinctions are even more tightly interdependent than we have surmised. However, we would require clear-cut evidence before inferring such differences in the relation between segmental and prosodic aspects of planning. The test case would be a single child who stops fricatives and fronts velars in syllable-initial position, but produces fricatives and

velars correctly in syllable-final position. Does such a child show the same prosodic effects on syllabification for both processes, or are the different segmental features differently affected by prosodic structure? Stephen would have been a case in point, but at the time of this investigation he was no longer fronting consistently and was repeating velars correctly in all domains. It was therefore not possible to compare the domains of fronting and stopping.

While 'phonological processes' in children involve only limited aspects of language processing, their very specificity makes them a valuable source of evidence for the mechanisms of phonological processing. The complex distribution of segmental substitutions provides us with a unique opportunity to investigate the relation between segmental features and prosodic structure in the syllabification of the word during articulatory planning. The inferences which emerge may be developed further by considering them in the context of impairments in articulatory planning other than that investigated here.

Acknowledgement

References

BLACK, M. and BYNG, S. (1986) Prosodic constraints on lexical access in reading. *Cognitive Neuropsychology*, **3**, 369–409.

BRETT, L., CHIAT, S. and PILCHER, C. (1987) Stages and units in output processing: some evidence from voicing and fronting processes in children. *Language and Cognitive Processes*, **3/4**, 165–177.

CHIAT, S. (1983) Why *Mikey,'s* right and *my key's* wrong: the significance of stress and word boundaries in a child's output system. *Cognition*, **14**, 275–300.

FOWLER, C. A., RUBIN, P., REMEZ, R. E. and TURVEY, M. T. (1980) Implications for speech production of a general theory of action. In B. Butterworth (Ed), *Language Production, Volume 1* (London: Academic Press).

HUGHES, R. E. (1983) The internal representation of word-final phonemes in phonologically disordered children. *British Journal of Disorders of Communication*, **18**, 79–89.

INGRAM, D. (1974) Phonological rules in young children. *Journal of Child Language*, **1**, 49–64.

INGRAM, D. (1986) Explanation and phonological remediation. *Child Language Teaching and Therapy*, **2**, 1–19.

KORNFELD, J. (1971) Theoretical issues in child phonology. In *Papers from the Seventh Regional Meeting, Chicago Linguistics Society*, pp. 454–468.

LIBERMAN, M. and PRINCE, A. S. (1977) On stress and linguistic rhythm. *Linguistic Inquiry*, **8**, 249–336.

SELKIRK, E. O. (1980) The role of prosodic categories in English word stress. *Linguistic Inquiry*, **11**, 563–605.

SELKIRK, E. O. (1984) *Phonology and Syntax: The Relation between Sound and Structure* (Cambridge, Mass: MIT Press).

SMITH, N. V. (1973) *The Acquisition of Phonology: A Case Study* (Cambridge: Cambridge University Press).

TOPBAS, S. (1988) *An investigation of the frequency effect and its influence on the acquisition of /k/, /t/, /tʃ/ in Turkish* (unpublished MSc thesis, City University, London).

Appendix 1a

Words used in repetition of fricative targets controlled for position relative to word boundaries and stress.

Initial	feed, fog, fat, fall, fun, sit, suit, safe, sock, sun
Second syllable, stressed	before, re'fuse, prefer, deserve, cassette, decide, beside, up'set, in'side, in'sult
Second syllable, unstressed	offer, sofa, toffee, river, over, 'present, answer, easy, pencil, music
Third syllable, secondary stress	interview, terrified, uniform, xylophone, atmosphere, microphone, exercise, aniseed, parasite, universe
Final	laugh, cough, safe, dive, give, miss, dice, rose, noise, face

Appendix 1b

Words in spontaneous/elicited production with fricative targets in word-initial, word-medial and word-final positions.

Initial

> Stopped: fit, found, farmer, find, from, for, fish, finger, food, fix, fell, flying, floor, film, sister, sit, someone, sometimes, superman, seesaw, saw, same, seen, say, sausages, silver, sellotape, some, so, zebra, sharp, sure, share, think, thing

> Correct: snake, swing, slipper

Second syllable unstressed

> Correct: diver, after, different, even, over, silver, sausages, sister, Lucy, person, scissors, tweezers, biscuit, lizard, easy, other

> Stopped: different, breakfast

Final

> Correct: miss, yes, this, these, 'cause, box, fix, case, was, is, have, if, off, knife, rubbish, fish, with, watch, plural morpheme and possessive morpheme attached to nouns, 3rd person singular attached to verbs, contracted 'be' and 'have' attached to subjects

Appendix 2

Constructions used in repetition of target fricatives controlled for position relative to word boundaries and phrasal stress.

Auxiliary 'pronoun	Where have 'I been
	What has 'he done
	Who does 'he like
	Where does 'he live
	What is 'he doing
	Have 'I got a car
	Is 'he working
	Has 'he gone
	Does 'he like tea
	Has 'he got a cold
Copula–'adjective/'preposition	The door is 'open
	The mum is 'old
	The man is 'angry
	The boy is 'ill
	That thing is 'odd
	The light is 'on
	The man is 'out
	The girl is 'in
	The party is 'over
	The telly is 'off
'Auxiliary–pronoun	Where 'have I been
	What 'has he done
	Who 'does he like
	Where 'does he live
	What 'is he doing
	'Have I got a car
	'Is he working
	'Has he gone
	'Does he like tea
	'Has he got a cold

Appendix 3a

Words used in repetition of target fricatives controlled for position in prosodic structure of word.

Between stressed V and unstressed V

easily, visible, accident, messenger, musical, decency, misery, possible, physical, positive, lovable, awfully, carefully, invalid, officer, envious, evident, confident, daffodil, difficult

Between unstressed V and unstressed V

innocent, Alison, medicine, decency, opposite, jealousy, fantasy, amazon, policy, heresy, Jennifer, colourful, benefit, Oliver, officer, interval, festival, paraffin, elephant, beautiful

Between stressed V and secondary stressed V

insect, consort, racist, incense, accent, insight, capsule, missile, docile, ozone, enzyme, 'upset, 'inside, 'outside, 'insult, Garfield, 'refuse, perfume, servile, morphine

---

Appendix 3b

Words used in spontaneous/elicited production with fricative targets in different prosodic positions within the word.

Between stressed V and unstressed V

    Correct: bicycle, accident, hospital, easily, sausages, Lucifer, Parsifal, buffalo, difficult, Davison

Between unstressed V and unstressed V

    Correct: Lucifer, Alison, venison

    Stopped: medicine, opposite, Davison, elephant, Parsifal, Oliver, Lucifer

---

Appendix 4a

Words used in repetition of intervocalic fricative targets in different phonotactic combinations.

Post-liquid
    Elvis, dolphin, Kelvin, willful, Alfie, selfish, salvage, skillful, pilfer, silver
Post-nasal/stop/fricative
    anvil, comfort, harmful, envy, infant, canvas, breakfast, obvious, spiteful, blissful

Appendix 4b

Words in spontaneous/elicited production with fricative targets in different phonotactic combinations.

Post-liquid
    Correct: silver, Alfie, Elvis, Kelvin
    Stopped: Alfie
Post-nasal/stop
    Correct: infants, breakfast, obvious
    Stopped: infants, breakfast, anvil, envy