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Why *Mikey's* right and *my key's* wrong: The significance of stress and word boundaries in a child's output system*

SHULAMUTH CHIAT

The City University, London

Abstract

The systematic errors children make in the course of phonological development, like adult production errors and adult phonological processes, can provide evidence of language production mechanisms. A detailed investigation of the environments in which velar stops are fronted by a phonologically delayed child reveals that fronting is dependent on both word stress and word boundaries; that it shows lexical exceptions; and that it occurs in output only. This distribution suggests that the child has output lexical representations which are independent of input lexical representations, and that the fronting error occurs in these output representations. It also suggests that prosodic features are crucial to the identification of articulatory features within these representations. Such an analysis has implications for theories of lexical access, and for the development of lexical access in children.

The systematic mispronunciations observed in young children's phonological development could be a major source of information about language production mechanisms and their emergence. Adult slips of the tongue have for some time been recognized as deviations produced by the mechanisms of language production which can throw light on those mechanisms. Children's production errors, too, are deviations arising in the production process which can help us identify the nature of the units and stages involved in that process. In contrast to adult errors, they are productive and systematic rather than

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one-off events. They provide evidence which can be assessed alongside adult data and in relation to adult models.

The crucial information, as with adult errors, is the linguistic description of the error and of the constraints which operate on it. This information reveals the unit of production which the child is working with at the point when the error occurs, and may tell us something about the internal structure of that unit.

Recent research into phonological development has described children's 'phonological processes' in isolated lexical items (e.g., Ingram, 1974; Smith, 1973; and see Chiat, 1979 for a summary of these processes). New directions in such research have turned to variation between words within the phonological system of one child, and variation between the phonological systems of different children (e.g., Ferguson and Farwell, 1975; Kiparsky and Menn; Leonard *et al.*, 1980). The result is a comprehensive description of the nature and range of deformations which typify the phonemic segments children produce. However, research in this paradigm has rarely looked at children's phonology in units other than lexical items, and has not, therefore, investigated properly the scope of children's phonological deformations. Phonological environment has only been mentioned when it provides a conditioning factor in segmental substitutions (e.g., in consonant harmony, where one consonant changes under the influence of a nearby consonant) and has not itself been of interest.

Amongst the rare exceptions to this generalization is Macken's study (1979) of a very young child's phonological system which shows regularities within this system to be word-governed. Macken argues that the word is the first important phonological unit, and that the phoneme only later becomes significant. However, at such an early stage of language development it is difficult to determine precisely the environment of a phonological process, since the environments the child controls are still very limited. Another significant exception to the widespread disregard for environment in developmental phonology is the analysis of data from a disordered child by Gandour (1981) (in fact, a re-analysis of data collected and analysed by Lorentz). Gandour, who is concerned with reduction and substitution processes affecting consonant clusters, argues that the relevant environment for these processes is the syllable. His argument is based on the fate of consonant clusters which occur medially in polysyllabic words, and are differentially affected according to their syllable position, e.g.,

lipstick → [lípsɪk]
BUT mistake → [mɪstéyk];

outer space → [æwdr̩féys]
BUT displease → [dɪsplíyz].

/st/ is reduced to [s] only if it is syllable-initial; similarly /sp/ coalesces into [f] only if it is syllable-initial.

This latter attempt at environmental analysis is rare in the literature. In general, we have no explicit information about whether a particular deformation which is claimed to occur initially, medially, or finally does so in syllables, phonological and/or non-phonological words (content or function words), intonation units, morphemes, constituents, clauses, or sentences. Since lexical items are the only units investigated, the crucial environment for a particular process — which may be greater or smaller than the word — remains obscure. We do not even know whether the environment is defined phonologically (e.g., syllable), syntactically (e.g., constituent), or both (e.g., clause and intonation unit). In summary, while we know a great deal about the effects of phonological processes on children's segmental phonology, we know little about the types of unit over which these processes operate, and hence about the aspect of production implicated in them. In the absence of such information, children's deviant utterances appear to be the product of a fairly homogeneous set of processes whose place in the mechanisms of utterance production is unknown and unquestioned. These processes may turn out to be quite heterogeneous when their place in language production is established.

The research presented below begins to explore aspects of phonological development as evidence of production mechanisms and their development. It focuses on one particular error within the output of a phonologically delayed child: the fronting of velar stops.

Pilot work on the spontaneous and imitated output produced by this child pointed to the following consistencies:

(1) Alveolar stops were extremely well preserved, while velar stops were frequently fronted,
e.g., key → [ti:]
go → [dəu]
can go to school → [dən dəu du duw]

(2) The relative stability of alveolar and velar stops was reversed only when an alveolar was assimilated to a following velar,
e.g., stick → [gɪk]
tiger → [gaɪgə].

(3) Fronting of velar stops appeared to be confined to word-initial position, so that velar stops were intact in medial and final positions as exemplified by *tiger* and *stick*.

(4) Stop consonants were subject to changes in voicing as well as place of articulation, but changes in voicing were not confined to a particular position within the word.

These output patterns suggested that this child would be a good candidate for investigating the scope of child errors as evidence of production mechanisms.

The aim of subsequent research with the child was to determine the precise scope of his errors, i.e., the type of unit, whether phonological, syntactic, or lexical, on which the errors were defined. The two experiments and analyses of spontaneous data reported below investigate the effects of word boundaries and stress on velar stops in the child's production and perception of single words, and in his production of connected speech. The results of these analyses provide a linguistic definition of the error and of the constraints operating on it. From this, we can infer the aspects of language processing involved in the error. Implications for theories of language production and for the establishment of lexical access processes in the child will be discussed.

The data reported below show extremely consistent patterns. It may nevertheless be argued that they tell us very little because they are unrepresentative: they are derived from a single subject, and one whose phonological output is acknowledged to be abnormal. Clearly we do need similar evidence from other children, normal and abnormal, to be confident that the claims made on the basis of this child's output are generally valid. At present, these claims can be conclusive only for this child. There is reason to believe, however, that this child *is* representative in the crucial respects, and hence that the findings will be corroborated by further evidence. Apart from segmental deformations, this child's utterances are entirely normal. They are contextually appropriate; they are age-appropriate from a syntactic and morphological point of view; and they show normal suprasegmental phonology. This suggests that all aspects of output processing except for those handling segmental phonology are intact, and can be assumed to rely on the same mechanisms as the rest of us use when producing utterances. Suppose, then, that the various deviations in the child's segmental phonology involve different linguistic units, and therefore implicate different aspects of production. There is no reason to think that the units themselves and the mechanisms of production which they imply are unique to the child. In fact, it is precisely the discrepancy between the child's segmental phonology and the rest of his language which allows us to use his output as a 'window' onto processing mechanisms by making inferences from the scope of his phonological deformations. In contrast to younger children, his language output is sufficiently clear, varied, and complex to permit consideration of the full range of linguistic units which could be significant in output. It is to be hoped that further research will eventually bear out these claims.

Experiment I

Method

Subject

Stephen was 5 years 8 months old when this experiment was carried out. He had been attending school for one year, and had been referred by the school for speech therapy at 4 years 10 months. No abnormalities in Stephen's development were reported by his mother or by the school, apart from the speech problem which was the reason for his referral to a speech therapist. His hearing was tested by an audiologist and found to be within normal limits. He was diagnosed as having phonological delay. Therapy over the preceding 10 months had focused on production of fricatives. There had been no noticeable improvement in Stephen's intelligibility between the time of referral and the present investigation.

Stephen was beginning to learn to read and write at this time, but was still pre-literate.

Procedure

Imitated and spontaneous data were elicited in order to investigate Stephen's output. The imitation tasks manipulated Stephen's output systematically, and so permitted the scope of phonological errors in his speech to be thoroughly investigated. Spontaneous output could not be controlled in the same way, but by submitting it to the same analysis as the imitated data, it was possible to show that the child's imitations were representative of his normal output and that any findings were not experimental artefacts.

The data were recorded on a Uher 4400 tape recorder, and were transcribed immediately after the session, using as much phonetic detail as was necessary to distinguish systematically different realizations of the phonemes involved in fronting. This phonetic transcription was accompanied by an orthographic version of the utterances.

Imitation tasks. Stephen was required to repeat single words or sentences uttered by the investigator. To make the task more palatable, he was given a puppet and was invited to "make the puppet say things I say". After his initial reluctance to repeat — at the first attempt, when I asked the puppet to "say things", Stephen's response was "He's too lazy today" — Stephen came to enjoy and even request imitation tasks. After Experiment I had been administered Stephen complained that one puppet had not had his fair share of repetition ("He's not worned out yet" was his comment) and all the

stimulus sentences were repeated at his will, in reverse order. Stephen proved very good at imitation, never missing out a word in single-word or sentence imitation.

The stimuli in these imitation tasks placed alveolar and velar stops in different positions within single words and within sentences. No other stops were present in the stimuli.

In the single word condition, the target was either initial, medial or final. Altogether, 44 words were tested. Twelve of these contained only one target, either initial or medial, and the remaining 32 contained two targets, either initial and medial, or initial and final. Of the words containing two targets, half used targets which agreed in place of articulation. In all, 36 alveolar stops and 40 velar stops were tested. The words were presented in random order.

In the sentence condition, there were at least two targets in each test sentence, and these occurred initially in consecutive words. The sequence of words containing the targets consisted of either two phonological (relatively stressed, content) words, or a non-phonological (relatively unstressed, function) word and a phonological word. The sequence of targets either agreed or disagreed in place of articulation. Altogether, 28 sentences were tested. These contained 28 initial alveolar stops, and 28 initial velar stops. Apart from these targets, there were 5 word-medial velars and 5 word-final velars within the test sentences. The sentences were presented in random order.

All stimulus words and sentences are listed in Appendix I.

Following transcription of the imitated data, the realization of each alveolar and each velar target was classified as incorrect (fronted for velars, backed for alveolars) or correct. The scores for alveolars and velars were then analysed statistically to determine whether they were affected by their position within the word (initial *versus* medial *versus* final), or the type of word in which they occurred (phonological *versus* non-phonological). Since the sentence imitation was administered twice (in different orders of presentation), there were two sets of results and these were compared for consistency.

Spontaneous data. The spontaneous data were collected by providing Stephen with a variety of toys and taping his speech while he played with these for about half an hour. This yielded an extensive set of data. Following transcription of these data, realization of alveolar and velar targets was scored and analysed in the same way as the experimental data, to allow comparison of the two conditions.

Thus, detailed contextual evidence of errors involving alveolar and velar stops was obtained for both imitated and spontaneous speech.

Results

The results from the imitation tasks and spontaneous data are presented in Tables 1 – 5. Stephen's realization of all target stops fitted one of the two specified categories, correct or fronted/backed (=incorrect). Visual inspection of the results indicates that they are extremely clear-cut showing:

(1) a near-100% effect of place of articulation and position within the word: only word-initial velars are fronted, and these are fronted whether the word is imitated or spontaneous, in isolation or in connected speech;
(2) almost no effect of word type (phonological or non-phonological).

The results were nevertheless analysed statistically, using the Omnibus programme (unified analysis of variance by ranks) (Meddis, 1980). For all significant results reported, $p < 0.001$.

Imitation tasks. Table 1 shows the treatment of alveolars and velars according to their position within a single word. There is a significant interaction between place of articulation and position within the word ($z = 5.04$), due to almost consistent fronting of initial velars. Table 2 shows the treatment of velars according to their position within a word, in a sentence. The effect of position on velars is again significant ($z = 5.35$). Table 3 breaks down the word-initial category according to word type, and reveals no difference between phonological and non-phonological words ($z = 0.40$, $p > 0.5$).

The near-identity of the results in the test and retest, presented in Tables 2 and 3, indicates the reliability of the findings.

Spontaneous data. These data show the same distribution as the imitated data. Table 4 gives a breakdown of alveolar and velar targets by their position within the word. Again, there is a significant interaction between place of articulation and position within the word ($z = 3.03$), due to fronting of initial

Table 1. *Word imitation: Initial versus medial versus final*

	Correct	Incorrect
Alveolar		
Initial	19	1
Medial	8	0
Final	8	0
Velar		
Initial	2	18
Medial	12	0
Final	8	0

Table 2. *Sentence imitation: Velars in word-initial versus word-medial versus word-final*

		Correct	Incorrect
First test			
Velar:	Initial	2	26
	Medial	5	0
	Final	5	0
Re-test			
Velar:	Initial	0	28
	Medial	5	0
	Final	5	0

Table 3. *Sentence imitation: Initial in phonological versus non-phonological words*

		Correct	Incorrect
First test			
Alveolar:	Phonological	18	0
	Non-phonological	10	0
Velar:	Phonological	2	16
	Non-phonological	0	10
Re-test			
Alveolar:	Phonological	18	0
	Non-phonological	10	0
Velar:	Phonological	0	18
	Non-phonological	0	10

Table 4. *Spontaneous data: Word-initial versus word-medial versus word-final*

	Correct	Incorrect
Alveolar		
Initial	58	9
Medial	36	0
Final	133	0
Velar		
Initial	8	51
Medial	21	1
Final	29	1

velars. Table 5 gives a breakdown of the word-initial category by word type, and again there is no difference between phonological and non-phonological words ($z = 0.66$, $p > 0.5$).

Interestingly, the few exceptions to these quite consistent patterns of preservation themselves show regularities. In *ALL* ten cases where alveolar targets failed to be preserved, they were followed by a velar target with which they were harmonized (e.g., *tiger* [gaɪgə]). The exceptional preservation of velars word-initially included one case of harmony. The other eleven exceptional velars appeared to be random, but there was some suggestion that preservation of initial velars was word-specific: certain items had initial velar intact. These items were *car*, *gun*, *camel*. Further support for such lexical specificity is provided by the spontaneous and experimental data collected with Experiment II.

The difference between initial and medial velars (whether they occur in phonological or non-phonological words) is exemplified by the following pairs:

... man can ... → [mæn dən]
BUT monkey → [mʌŋgɪ];
... to kill ... → [də dɪl]
BUT tickle → [dɪgəʷv]/[gɪgəw];
... can go → [dən dəu]
BUT cooking → [tʊkɪn].

These examples of fronting can be contrasted with errors of voicing. Though not investigated systematically, the voicing of voiceless stops which occurs in the spontaneous data suggests a different pattern from that observed in fronting. Voicing is found word-initially, word-medially, and word-finally, provided the target is pre-vocalic, e.g.,

Her can look after these two
[ɜ: dən lʊg ɑ:htə di:z du:]

Table 5. *Spontaneous data: Initial in phonological versus non-phonological word*

	Correct	Incorrect
Alveolar		
Phonological	40	9
Non-phonological	18	0
Velar		
Phonological	6	36
Non-phonological	2	15

Futhermore, word-final stops may be voiced whatever the syntactic boundary, as long as a vowel follows. Thus there are even examples of clause-final voicing:

when he goes back and he sees them eaten up ... →
[wɛn i: dəʊz bæg ænd i: li:z əm i:ʔn ʌp].

In contrast, across all the data collected there is just one example of a final velar stop being fronted (as if it were an initial stop):

and they walk on water →
[æn eɪ wɔ:d ɒm wɔ:də].

In all other cases, place of articulation is preserved word-finally, even before a vowel, though voicing may not be:

and they can walk on water →
[æn æ dəm wɔ:g ɒm wɔ:də];
He's gonna put it on his van and take it away →
... [ən deɪk ɪʔ əweɪ].

Presumably, the unique exception [wɔ:d ɒm] is a 'slip of the tongue' within Stephen's output system.

Discussion

This experiment established that Stephen fronts velars word-initially in phonological and non-phonological words, but preserves velars word-medially and word-finally. This remains true in connected speech; unlike voicing, which affects stops pre-vocalically, fronting is defined in terms of position within the word.

The experiment does not, however, tell us exactly where, within words, velars are fronted. This is because all the words in which medial velars occurred in the data showed the same stress pattern, with the velar as the offset of a stressed syllable and onset of an unstressed syllable, as in *finger* → ['lɪŋgə]. Hence, we do not know whether the difference between *monkey* → ['mʌŋgɪ], where the velar is preserved, and *my key* → [maɪ 'di:], where it is not, is due to the difference in stress pattern or word boundaries. In order to clarify the effects of these two factors, a follow-up experiment investigated Stephen's treatment of velars in contexts where stress and word boundaries were systematically contrasted. Further discussion must await the results of this experiment.

Experiment II

Method

Subject

Experiment II was carried out a month after Experiment I, when Stephen was 5 years 9 months old.

Procedure

This experiment again elicited imitated data whose analysis could be compared with a similar analysis of spontaneous data. Because alveolar targets had proved to be of little interest, only velar targets were investigated in these analyses. The imitation task this time was followed by a discrimination task to investigate whether Stephen could perceive the difference between alveolar and velar stops in the various contexts in which he himself confused them.

Imitation tasks. The procedure for collecting imitated data was the same as in Experiment I.

The imitation task placed target velar stops in six different word boundary and stress conditions:

(1) Word with medial velar stop before unstressed vowel, in isolation or in sentence e.g., *'record* (noun).
(2) Word with medial velar stop before stressed vowel, in isolation or in sentence e.g., *re'cord* (verb).
(3) Word with initial velar stop before unstressed vowel, in sentence e.g., We will *compete.*
(4) Word with initial velar stop before stressed vowel, in sentence e.g., You will be *cosy* here.
(5) Unstressed word with initial velar stop, following stressed word, in sentence e.g., SHE *can* sing but HE *can* dance.
(6) Unstressed root of compound with initial velar stop, following stressed root, in isolation e.g., *teacup.*

These different combinations incorporate all the crusial environments for investigating the effects of stress and word boundaries on the behaviour of velars. Conditions (1) and (2) have the velar target in the same position relative to word boundaries, but a different position relative to word stress. This is also true of conditions (3) and (4), which correspond to conditions (1) and (2) respectively in the relation of the velar target to word stress; they differ from (1) and (2) in the relation of the

velar target to word boundaries. Condition (5) is like (1) and (3) in the relation of the target to stress, but this stress is no longer word stress because the stressed syllable is separate from the target word rather than being part of it. Condition (6) is intermediate between (1) and (5); the relation of the stressed syllable to the target is closer than in (5) but not as close as in (1).

All the stimuli used in these six conditions are listed in Appendix II. It will be noted that the number of stimuli in different conditions varies considerably. This is due first to the fact that some combinations of stress and syllable structure are characteristic of words which Stephen would be unlikely to know, so that possible stimuli were limited [e.g., condition (3)]. It is also due to the fact that the other experimental data and spontaneous data provided numerous examples of some of the above combinations [e.g., condition (4)]. In these cases examples were only included to test certain near-minimal pairs, e.g.,

You eat *because* you're hungry
versus The ba*by calls* its mother;
He always *forgets* the answer
versus This is *for goats* to eat;
aching versus *I can* read.

Interest in such minimal pairs also accounts for the fact that stimulus words sometimes occurred in isolation and sometimes in sentences. These variations in the different conditions were not a problem for the statistical analysis used.

It may finally be noted that, unlike the stimuli in Experiment I, these stimuli did contain stops other than the targets. Spontaneous data had indicated that other stops did not affect velars so there was no reason to exclude them. This made it easier to construct the range of stimuli required.

The stimuli were administered in three blocks. All the single-word items from conditions (1) – (5) and the compounds in condition (6) were presented together, in random order. The sentences in conditions (1), (2) and (4) were presented together, in random order, in the same session. One week later, the sentences in conditions (3) and (5) were presented together, with five filler sentences, in random order.

Spontaneous data. The collection of spontaneous data was as in Experiment I.

All the data, imitated and spontaneous, were transcribed immediately after the session. Velar targets in the spontaneous data were categorized in terms of the different conditions tested in the experiment, so that the two sets of data could be compared with respect to any contrasts represented in both. All targets were scored as correct or fronted. The results were analysed statistically to determine the effects of stress and word boundaries. The effects of word-type (phonological versus non-phonological) and position within the word (initial versus medial versus final) were again analysed in the spontaneous data so that they could be compared with the effects observed in Experiment I.

Discrimination task

Stephen's discrimination between alveolar and velar stops was tested by asking him to post a red car in a box when he heard /dəu/, and a green car when he heard /gəu/. Five exemplars of each were presented, in random order. This was repeated with /fə'dɛt/ and /fə'gɛt/, then /də'rɛkt/ and /kə'rɛkt/. After these 30 items had been tested, Stephen was given three more pairs of items to discriminate *WITHOUT* being told which colour car went with which member of the pair. Thus, he had not only to discriminate the pair but to identify which of the pair belonged to the alveolar category (i.e., was like /dəu/, /fə'dɛt/, /də'rɛkt/), and which belonged to the velar category (i.e., was like /gəu/, fə'gɛt/, /kə'rɛkt/). The three pairs presented were /dæn/ and /kæn/ , /ə'dɛn/ and /ə'gɛn/, /dəm'pi:t/ and /kəm'pi:t/. Each pair was presented separately with three instances of each member randomly ordered with respect to one another.

All the stimuli used in this task were items in which Stephen himself fronted the velar target.

Results

The results of Experiment II are presented in Tables 6 and 7. Again realization of all the targets fitted the categories correct or fronted, apart from one omission of a target. Again, the results a.e extremely clear-cut even to the naked eye, indicating a near-100 percent effect of stress on word-medial velars. The data were analysed statistically using the Omnibus programme, and for all results reported as significant, $p < 0.001$.

Imitation tasks. Table 6 shows the treatment of velars according to their position relative to word boundaries and stress. There is a significant interaction between these factors ($z = 4.29$), due to the exceptional preservation of medial velars preceding an unstressed vowel. Medial velars preceding a stressed vowel and initial velars preceding a stressed or unstressed vowel are almost consistently fronted. The stress effect does not operate across word boundaries. Even when their relation to stress is kept constant (i.e., they follow a stressed vowel and precede an unstressed vowel), there is a significant difference between word-initial and word-medial velars ($z = 4.41$): the initials are fronted but the medials are preserved.

Spontaneous data. The spontaneous data, presented in Table 7, are again consistent with the imitated data. Medial velars are preserved before an unstressed vowel, but not before a stressed vowel ($z = 4.24$). The spontaneous data also corroborate the findings of Experiment I. Again, all word-final

Table 6. *Velars in imitation: Stress and word boundaries*

	Correct	Fronted	Omitted
Word-medial			
Before unstressed vowel	17	1	0
Before stressed vowel	3	14	0
Word-initial			
Before unstressed vowel	0	5	1
Before stressed vowel	0	4	0
Initial of unstressed word following stressed word in sentence	0	6	0
Initial of unstressed root following stressed root of compound	2	3	0

Table 7. *Velars in spontaneous data: Stress and word boundaries*

	Correct	Fronted
Word-initial		
Phonological	15	78
Non-phonological	0	25
Word-medial		
Before unstressed vowel	10	0
Before stressed vowel	0	8
Word-final	26	0

velars are preserved and most word-initial velars are fronted whether they occur in phonological or non-phonological words. The slight superiority of phonological words is probably due to the existence of lexical exceptions to fronting which involve only phonological words.

That is, as in Experiment I, the experimental and spontaneous data suggest that certain words are exceptions to the fronting error. There were more examples of *car* (4/4), *camel* (2/2), *gun* (3/3), which were exceptionally correct in Experiment I. Possible exceptions which had not been attempted before were *crabs* (2/2), *begin* (2/2). These consistently correct items together account for 13 of the 22 exceptions recorded across all the data.

Interestingly, the six compound words, which were not subjected to any statistical analysis, show variation in the realization of the target velar. In the case of *egg cup*, *teacup*, *teacake*, *dressing gown*, the velar was fronted. (These

may be contrasted with, for example, *angry* and *ticket* where the velar is preserved.) In the case of *waistcoat* and *racing car*, the velar was preserved as it was in four instances of *zoo-keeper* which Stephen produced in the spontaneous data. It may be that Stephen is inconsistent with velars which begin the unstressed roots of compounds, or it may be that *car* and *keeper* are exceptions to fronting and so compounds that contain them are intact.

The range of findings in Experiment II are illustrated by the following examples of imitated and spontaneous data:

(1) *Stress effect on medial velar*: word-medial velar fronted before stressed vowel and preserved before unstressed vowel

because → [bɪ'dɒz]
BUT baker → ['beɪgə];
re'cord (verb) → [ɪ'dɔ:d]
BUT 'record (noun) → ['rɛgɔ:d];

What are these called again? I know but I forgot →
... [dɔ:ld ə'dɛn] ... [aɪ ə'dɒt]

BUT Can't get him on my finger →
[dɑ̃:ʔ dɛdɪm ɒnmaɪ 'lɪŋgə].

(2) *Absence of stress effect on word-initial and word-final velar*: word-initial velar fronted and word-final velar preserved whatever their relation to stressed and unstressed vowels in the word

I collect stamps → [aɪ də'lɛk dæmps]
AND Goldilocks → ['dɒldɪlɒks]

(3) *Absence of stress effect across word boundaries*: word-initial intervocalic velar fronted and word-final intervocalic velar preserved whatever their relation to stressed and unstressed vowels

teacake → ['di:deɪk]
BUT ticket → ['dɪkɪt];
This is MY key → [ðɪs ɪz 'maɪ di:]
BUT This is Mikey → [ðɪs ɪz 'maɪgɪ];
... back out → [bæg 'aʊt]
BUT ... because → [bɪ'dɒz]

Discrimination task

Stephen responded correctly to all 48 items in this task. He had no problem in classifying members of a minimal word pair into the alveolar or velar group

even when he had not been given a demonstration of that pair (see procedure).

Summary of results

The generalization which now emerges is that Stephen has no problem with velars in perception; in production he preserves velars

(1) word-finally
(2) word-medially before an unstressed vowel,

and he fronts velars, except in specific lexical items,

(1) word-initially
(2) word-medially before a stressed vowel.

The evidence that Stephen's realization of velars depends crucially on word boundaries is that initial and final velars do not behave like medials even when they occur intervocalically in connected speech.

If fronting of velars depends on word boundaries, it is important to establish what constitutes a word, i.e., whether the boundaries of non-phonological words, including unstressed function words, roots of compounds, and affixes, serve as boundaries for fronting. We have found that unstressed function words are treated in the same way as phonological words. They do not attach to neighbouring stressed syllables in connected speech, since their initial velar is fronted even following a stressed vowel (HE *can dance* → ['hi: dən da:ns]), and their final velar is not fronted even before a stressed vowel (*back out* → [bæg 'aʊt]). Roots of compounds, on the other hand, show inconsistency, perhaps reflecting their hybrid nature. It is clear, nevertheless, that fronting *CAN* occur in the initial velar of unstressed roots (e.g., *teacup, teacake*, and notably *egg cup*, where the first velar is preserved but not the second). This indicates that the roots of compounds are sometimes treated as separate words, even though they are phonologically equivalent to the unstressed syllables of non-compounds. It seems likely that where the root of a compound is familiar as a free form, its initial velar undergoes fronting as in the free form, even though it is intervocalic within the compound. As far as affixes are concerned, we have no evidence. Unfortunately English has no affixes with velars in the crucial places, so it was not possible to determine how velars at the boundaries of affixes are realized.

In contrast to the fronting error, it was observed that Stephen's voicing error was not constrained by word boundaries.

Discussion

We will now consider why and how these results are significant for theories of language processing and its development.

The environments in which fronting and voicing occur are not unique to Stephen's phonological system. Phonological generalizations in adult systems can certainly be sensitive to stress and word boundaries. For example, the distributions of /h/ and /ŋ/ in English RP are very similar to the distributions of Stephen's fronted and non-fronted velars respectively. His fronting error, then, is analogous to phonotactic generalizations in the adult phonological system. Such generalizations contrast with assimilatory processes, which cross word boundaries. Investigations into processes such as palatalization and alveolar flapping (Cooper and Paccia-Cooper, 1980; Paccia-Cooper and Cooper, 1980) show that these processes do cross word boundaries and are blocked only by certain major syntactic boundaries. Stephen's voicing error is analogous to these assimilatory processes.

As a phonotactic generalization, the distribution of Stephen's fronting error is not especially significant. What is significant is that Stephen created such a phonotactic generalization when it did not occur in the input he received. It must therefore be the product of his language processing system, and must reflect the properties of such a system. Any model of language processing must therefore be able to account for the fronting error and its distribution. Specifically, it must account for the fact that an error in a segmental feature is

(1) dependent on the position of the feature relative to word boundaries,
(2) subject to lexical exceptions,
(3) dependent on the position of the feature relative to word stress,
(4) confined to production.

We will consider each of these factors in turn.

Implications for theories of language processing

Effects of word boundaries

An error of the kind involved in fronting could conceivably occur at different points in the production process. It could occur in lexical representations accessed for output, or it could occur at some stage of translating lexical representations into articulatory output. The fact that the error is constrained by word boundaries, rather than by the boundaries of a phonological unit such as a syllable, suggests that fronting occurs in lexical representations. If the error occurred at a stage following lexical access, i.e., in the execution of

phonological output, it seems odd that it should respect word boundaries. At the point when execution is being planned, word boundaries are surely superfluous. Accordingly, we find phonological errors which do fail to respect word boundaries: Stephen's voicing error is an example. Presumably these errors do occur at the stage of execution. There would seem to be no good reason for postulating two stages of execution, one with word boundaries still specified, and one following elimination of word boundaries. A more economical analysis is that the fronting error respects word boundaries because it occurs in the phonological representation of words.

Lexical specificity

This analysis is reinforced by a second feature of Stephen's data: the apparent existence of lexical exceptions to fronting. If fronting operated at a stage of execution rather than access, it could not be specified on a word-by-word basis. It would therefore be impossible to explain why specific lexical items are not subject to fronting though they meet the phonological conditions for fronting. On the other hand, if fronting is an error in lexical representations, lexical exceptions to the error are unsurprising.

Effects of word stress

The fact that a segmental feature is realized differently according to its position relative to word stress suggests that segmental features are not independent of prosodic features in lexical representations. Rather, segmental features are defined in terms of prosodic features. Lexical representations are not, then, strings of phonemes on which stress is marked, but prosodic structures on which segmental features are specified. According to this analysis, the phoneme /k/ is not a significant element in lexical representation, but the features velar and plosive as the onset of a word-initial stressed syllable are.

This outline is consistent with the finding that in adult slips of the tongue, segmental errors involve sounds which occupy the same position within the syllable (Fromkin, 1973) and word (Garrett, 1980). Most significantly for the claims based on Stephen's data, Garrett observes that in segmental errors "The interacting elements are metrically and phonetically similar ... Stressed syllables interact with other stressed syllables; stressed and unstressed do not interact", and "The environments of 'moved' elements ... are similar: word initial segments exchange with (copy, or shift to) word initial segments, medial with medial and final with final" (Garrett, 1980, p.184). This subordination of segmental features to the syllable has also been observed in work on perception, both in infants (Mehler and Bertoncini, 1979), and in adults (Liberman *et al.*, 1967; Massaro, 1972; Savin and Bever, 1970; Warren, 1971). What is novel in the present analysis is that these characteristics of phonolog-

ical processing are attributed to the way that words are phonologically represented, not as sequences of phonemes, but as prosodic structures with features attached to positions within those structures.

Discrepancy between input and output

Attributing the fronting error to lexical representations accounts for the fact that it is constrained by word boundaries and is subject to lexical exceptions. Treating lexical representations as prosodic structures to which features are attached accounts for the fact that fronting is sensitive to word stress. However, neither of these hypotheses accounts for the fact that fronting is confined to output, and that Stephen discriminates velars perfectly in input. The only way to maintain the claim that fronting occurs in lexical representations and at the same time account for the discrepancy between input and output is to posit separate lexical representations for input and output. If fronting is an error in lexical representations, it must be in lexical representations for output only.

This analysis is incompatible with most current models of lexical access. Most theories of language production incorporate a central lexicon (e.g., Fromkin, 1973). They allow at least two routes into that lexicon: a route for output via semantics, and a route for input via phonology. Forster (1976), for example, has a phonological file and a semantic/syntactic file which give access to a master file (central lexicon). In this case, the master file appears to be neutral between comprehension and production. The lexicon proposed by Fay and Cutler (1977), on the other hand, is biased towards comprehension in order to account for phonologically based selection errors (malapropisms). Butterworth (1980) comes close to eliminating the central lexicon when he points out that lexical organization may involve *TWO* sets of items, one semantically organized and one phonologically organized, together with a mapping relation between these. Here, the central lexical representation is replaced by a mapping relation between two representations. All these models share one assumption: that the same phonological representation of a lexical item is accessed in input and output, either from a central lexicon (Fromkin; Fay and Cutler; Forster) or from a phonological listing of lexical items (Butterworth). Only one model of language processing eliminates this assumption: the logogen model (Morton and Patterson, 1980). This model posits separate input and output logogens which are connected to each other and to the semantics. It does not, therefore, treat words as neutral representations accessed in all modalities. Rather, a word can be seen as a set of linked access codes, which are its logogens. The data from Stephen, as analysed above, support this very different conception of lexical representation as a set of access codes.

The main argument that is advanced for a single lexical representation is

that it is more economical (e.g., Fay and Cutler, 1977). Listing an item twice is taken to involve duplication and is therefore considered implausible. But economy in storage surely cannot be measured in the abstract, without taking into account the requirements of on-line production and comprehension processes. Consideration of these requirements, together with evidence of on-line production and comprehension processes (e.g., Marslen-Wilson and Tyler, 1980) may point to distinct representations of lexical phonology.

Overall implications for lexical access

All the properties of Stephen's fronting error can be explained if we assume that it is an error in a prosodically defined feature of output lexical representations. This analysis entails distinct lexical representations for input and output, i.e., input and output logogens. The analysis also has implications for the internal structure of output representations, and thus goes beyond the logogen model. It implies that output lexical representations are prosodic structures on which articulatory features are specified.

This outline of lexical access derived from Stephen's data could contribute to analyses of other data involving lexical access processes, e.g., malapropisms, tip of the tongue phenomena, and word finding problems in aphasics. Because Stephen's error arose in the course of development, it also raises questions about the emergence of lexical access processes in children.

Fronting and the development of lexical access

I have suggested that fronting reflects the incorrect specification of a prosodically defined articulatory feature in output lexical representations. Why should such an error happen? More specifically, why should a set of articulatory features depend on the prosodic features of the word in which they occur? One possibility is that the child relies on prosodic features to identify word boundaries and establish the internal structure of words; in this case, internal word structure (the segmental features of the word) is determined for prosodically defined units, and could be expected to be sensitive to prosodic features.

I have discussed the problem of word identification in detail in Chiat (1979) where I pointed out that the majority of words are not acquired in isolation, but must be segmented from the stream of speech; and that the main cues to segmentation in English are prosodic, apart from phonetic features (e.g., aspiration) which mark syllable boundaries. In the absence of semantic and phonotactic features (precisely those features which are not yet available to the language-acquiring child), adults have been found to use stress and

rhythm to identify word boundaries (Nakatani and Schaffer, 1978). If the child uses these prosodic cues to establish where words begin and end, it is not surprising that the feature structure of words is specified within prosodic parameters. It is not surprising that an error in the feature structure of words is sensitive to their prosodic structure.

This suggestion that prosodic factors may play a key role in the development of lexical access processes requires further elaboration and investigation. Cross-linguistic data could provide a testing ground. If the child does use prosodic cues to tackle word segmentation, cross-linguistic differences in prosody and word juncture should have effects on development. One reason why prosodic cues can contribute to word segmentation in English is that unstressed syllables and unstressed words tend to occur in different places in prosodic structure. The unstressed syllable of a bisyllabic word typically follows the stressed syllable, whereas the unstressed (non-phonological) word of a word sequence typically precedes the stressed word. This discrepancy would not exist in a language which had word-initial stress but which, unlike English, placed non-phonological words after phonological words. Here, prosodic factors would not distinguish between an unstressed syllable of a word and a non-phonological word, since both would be post-stress syllables. One might then predict that the child would initially treat the non-phonological word as part of the phonological word. If an error like fronting occurred, it might then ignore boundaries between phonological and non-phonological words, treating the initial of a non-phonological word as a medial. Development in such a language should thus result in

(1) more word segmentation errors,
(2) different distributions for errors such as fronting.

With regard to (1), it is interesting that segmentation errors are extremely rare in English-speaking children, despite the problem which segmentation would theoretically appear to pose for the child. Segmentation errors are not recorded in the now extensive child language literature on English. Could it be that prosodic structure in English simplifies the child's task? It would be interesting to know whether segmentation errors do occur in other languages, and if so, what their relationship is to the prosodic structure of the language. Do more errors occur in the acquisition of French, for example, since French provides fewer prosodic cues to word boundaries? I would suggest that the apparently intractable theoretical problem of how the child successfully breaks down the stream of speech to identify and register word forms could most usefully be pursued in developmental studies of lexical acquisition in different languages.

Conclusion

A detailed analysis of the constraints on one phonological error in one child's output has proved to have far-reaching implications. It has shown that such an error may be sensitive to word stress and word boundaries, i.e., to the prosodic structure of words. Thus, the child in this study fronts velars word-initially, and word-medially before a stressed vowel, but preserves them word-finally and word-medially before an unstressed vowel. The error is confined to production, and appears to be subject to lexical exceptions within production. The implication of this distribution, I argue, is that the error occurs in lexical representations, and that these representations are specific to output. A further implication is that these output representations consist of prosodic structures on which articulatory features are specified. The dependence of the child's output error on the prosodic structure of the word, I suggest, may be due to the child's reliance on prosodic cues to determine the boundaries and internal structure of words.

This analysis gives rise to a number of hypotheses which could be assessed in relation to a wide range of data. Normal and pathological errors made by adults and errors made by children learning different languages are vital in testing and developing these hypotheses. Theories of production processes should be able to accommodate these independent data.

The theoretical advances which emerge from such analysis may provoke new questions about quite different areas of normal and pathological language. Stephen's data, for example, indicate that he has problems with the finer points of segmental phonology, but that he can cope with all the complexities of processing prosodic structure. Suppose that a child was unable to cope with these complexities. Given the hypothesized importance of prosodic structure in segmenting the speech chain, the ability to process prosodic structure is a prerequisite to segmentation, hence to establishing lexical representations for word recognition and word output. If these hypothesized connections do exist, a problem with processing prosodic structure could be an effective block to language development. Might such an impairment underlie, or partially underlie, the problems shown by some children (children with developmental dysphasia) with aspects of language apart from segmental output?

One conclusion can certainly be drawn from this investigation into the complex environment in which one child fronts velars: the speech of children like Stephen could have a great deal to say to us.

Appendix I

Stimuli used in Experiment I. (Target alveolar and velar stops are underlined).

Stimuli used in word imitation task
Initial alveolar: tea, toe, door, die.
Initial velar: key, car, gay, go.
Medial velar: making, lucky, wriggle, wagging.
Initial alveolar + final alveolar: tight, dad, dot, toad.
Initial velar + final velar: cake, cook, kick, gag.
Initial alveolar + final velar: tick, dog,duck, tag.
Initial velar + final alveolar: cat, get, gate, kid.
Initial alveolar + medial alveolar: tighter, teddy, daughter, tidy.
Initial velar + medial velar: cooking, kicking, giggle, gagging.
Initial alveolar + medial velar: tickle, talking, turkey, ticket.
Initial velar + medial alveolar: kitten, getting, curtain, cuddle.

Stimuli used in sentence imitation task
(1) Phonological word + phonological word
Alveolar–alveolar: We have ten toes.
Here are two doors.
These do tear.
Velar–velar: They are gay games.
We love green grass.
We love cooking cakes.
Alveolar–velar: We have two keys.
They're tall girls.
They do giggle.
Velar–alveolar: We love gay days.
We will kick Tom.
Mummy's cooking tea.
(2) Non-phonological word + phonological word
Alveolar–alveolar: We love to dance.
We ran to town.
Here's something to do.
Velar–velar: We can call.
We can giggle.
We can kick.
Alveolar–velar: They're nice to girls.
We love to kick.
We love to giggle.

Velar–alveolar: The man can turn.
The man can dance.
The man can talk.

(3) Phonological word + non-phonological word
Velar–alveolar: Where will he go to?
Who will he call to?
Which hill will he go down?
Which hill will he call down?

Appendix II

Stimuli used in Experiment II. (Target velar stops are underlined).

(1) Word with medial velar stop before unstressed vowel
In isolation:
baker, angry, begging, foggy, sucker, uncle, whiskers, record, beckon, eager, aching, ticket, basket, dragon, rascal, packet.
In sentence:
We will hear the record.
You eat because you're hungry.

(2) Word with medial velar stop before stressed vowel
In isolation:
because, agree, begin, forget, secure, record, become, uncover, peculiar, okay, again.
Also: in case, of course (one or two words?)
In sentence:
We will record this song.
You eat because you're hungry.
He smiled because he saw you.
He always forgets the answer.

(3) Word with initial velar stop before unstressed vowel, in sentence:
I collect stamps.
The wire is connected.
That is correct.
I am confused.
We will compete.
That man is colossal.

(4) Word with initial velar stop before stressed vowel, in sentence:
This is for goats to eat.
He will be gone soon.

You will be cosy here.
The baby calls its mother.

(5) Unstressed word with initial velar stop, following stressed word, in sentence:
This isn't 'your key.
This is 'my key.
'She can sing but 'he can dance.
'I can read.
'You can write.

(6) Unstressed root of compound with initial velar stop, following stressed root, in isolation:
teacup, waistcoat, dressing gown, racing car, egg cup.

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Résumé

Les erreurs systématiques trouvées pendant le développement phonologique peuvent fournir, au même titre que les erreurs de production et les processus phonologiques des adultes, des preuves sur les mécanismes de production du langage. Une recherche détaillée des contextes dans lesquels les plosives velaires sont avancées ('fronted') chez un enfant phonologiquement retardé montre que le 'fronting' dépend du stress et des frontières du mot, présente des exceptions lexicales et se produit en production uniquement. Ces caractéristiques suggèrent que des représentations lexicales de sortie de l'enfant sont indépendantes des représentations lexicales à entrée et que les erreurs de 'fronting' ne se produisent que dans les représentations de sortie. Cela suggère aussi que les traits prosodiques sont essentiels pour l'identification des traits articulatoires dans les représentations. Une telle analyse a des implications pour les théories de l'accès lexical et pour le développement de l'accès lexical chez les enfants.