A Unified Theory of Final Consonant Deletion in Early Child Speech[1]

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0.0 Introduction

It is a well documented fact that children's first utterances lack final consonants (Velten, 1943; Leopold, 1947; Smith, 1973; Ingram, 1974). That is, in the first stages of speech production, children's utterances are predominately of the type consonant-vowel (CV) as opposed to consonant-vowel-consonant (CVC). This is true even when the target word is of the latter type in adult speech; when a child attempts an adult CVC word, she tends to drop the final consonant (or coda) and produce the word as CV. For example, a child might incorrectly produce the adult CVC word "big" as [bɪ], dropping the final [g].

There are at least three logically possible explanations of this phenomenon. The typical explanation given is based on *production* constraints. That is, children drop codas in CVC syllables because sounds in final position require more advanced planning than any other sound in the utterance. This difficulty causes the child to omit the coda.

An alternative to this view is an explanation based on *perceptual* constraints. These constraints affect the child's representation of utterances in the lexicon: that is, a child omits final consonants because she has incorrectly encoded a CVC word as a CV word due to misperception of the adult acoustic signal.

A third alternative is based on constraints within the child's *grammar*. That is, a child drops codas because constraints within her emerging grammar tell her that her language only has syllables of the type CV.

The diagram in (1) below illustrates how each of these theories hypothetically affects a child's pronunciation of the word "cat" (phonetically, [kæt]):

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(1) Possible Explanations of Coda-Loss[2]

REP=representation, mispercep=misperception

	INPUT	process	LEXICAL REP	process	OUTPUT
PROCESSING					
Error due to production →	[kæt] →	n/a →	/kæt/ →	simplification →	[kæ]
Error due to mispercep →	[kæt] →	mispercep →	/kæ/ →	n/a →	[kæ]
GRAMMAR					
Error due to faulty grammar →	[kæt] →	<CV>[3] →	/kæ/ →	n/a →	[kæ]

In this paper, I argue that none of the explanations above can *by itself* explain coda-loss in early child speech. Instead, I propose that final consonant deletion can only be accounted for by a combination of the properties of two of the theories. Specifically, I argue that both the grammatical theory and the production theory are necessary to explain coda-loss. I also argue that only these two theories are involved in the phenomenon and, thus, that the perceptual theory does not play a role in this domain. I base my arguments on data collected and analyzed for one child, age 18 to 22 months.

0.1 Organization

The organization of the paper is as follows: Section 1 outlines in detail each of the theories mentioned above, including a discussion of their unique assumptions and predictions. Section 2 furnishes the details regarding the subject and the data to be analyzed. Sections 3-7 present five different analyses of the data along with a discussion of the results for each. Sections 8 and 9 conclude the paper with a summary of the results of each test and a discussion of the conclusions that must be drawn from these facts.

1.0 The Three Theories

In the following sections, I outline the production theory (1.1), the perceptual theory (1.2), and the grammatical theory (1.3). In 1.4, I review the predictions of each of the theories and outline the possible tests to be performed.

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[2] Many thanks to Janet Nicol for help with the chart which follows.

[3] <CV> stands for that process which causes only CV syllables to be produced; this will be discussed in detail in Section 3. I represent <CV> as occurring following input, but logically it could occur directly prior to output. This will also be discussed in Section 3.

1.1 The Production Theory

1.1.1 Properties

A plausible production theory of coda-loss focusses on the fact that children in the first stages of speech production do not have full motor control over their articulators. This makes it difficult for a child to correctly produce many sounds in her language and may result in a child's omission of sounds or substitution of "easier" sounds for more complicated ones (Locke, 1983). Even more difficult for the child is the production of longer utterances; these require more advanced planning from the child and involve a more complex series of motor gestures (Menn, 1978). This predicts that in a CVC syllable, the final consonant is the hardest one to produce as it requires the most advanced planning. Because the task of closing off the syllable is too complicated, the child's attempts to produce a CVC word sometimes fail. This causes the final consonant to be dropped.

1.1.2 Predictions

If this is true, then a child's progression from CV to CVC syllables (and larger) should proceed at a relatively uniform rate. As the child becomes older and as her vocal apparatus matures, she will have better control over her articulators and be more adept at coordinating and planning a more complex series of motor gestures. Such articulatory "agility" is unlikely to develop suddenly and so the child's speech should reflect the gradual maturation of her control over her vocal tract. A child should produce very few CVC words successfully in her earlier, less stable stages, but produce increasingly more correct CVC utterances as she gets older.

Another prediction of a production theory arises when the difficulties outlined above are coupled with a child's general difficulty in producing the more complicated sounds in her inventory (such as, [č] or [š]). That is, once the child has begun to successfully produce consonants in final position, those sounds that appear in coda position should be the 'easier' ones for a child to articulate.

Finally, a production theory also predicts that a child may make fewer attempts at producing CVC words than CV words overall. If a child is aware that certain types of utterances will be difficult for her to produce, she may very well avoid them. The phenomenon of "selective avoidance" in children's speech is typically studied with respect to individual phonemes only (Ferguson and Farwell, 1975; Drachman, 1975). These studies show that children avoid consonants that are difficult for them to produce. Later studies by Schwartz and Leonard (1982) suggest that children also avoid *structures* which they know are difficult. Their studies show that when children do not have a form of the type CVC in their repertoire, they tend to avoid new or nonsense words with those structures. These findings lend support to the prediction outlined here and also suggest that CVC words attempted should suffer from both types of avoidance: phonemic and structural. If this is true, such avoidance should reflect itself in the child's speech. There should be fewer CVC words attempted than CV words in her early stages. As she is better able to produce codas and as she becomes aware that the task is less difficult, increasingly more CVC words should be attempted.

1.2 A Perceptual Theory

1.2.1 Properties

One perceptual explanation of the coda-loss phenomenon is based on the notion that a

child incorrectly encodes a CVC utterance as CV in her lexicon[4]. Such a mistake could arise from the fact that adults often produce codas that are acoustically "indistinct". That is, adults often do not release final consonants. For example, a word like "cat" might be pronounced [kæt̚] by the adult, where the [t] achieves closure at the alveolar ridge, but there is no following release of air. The child might assume, as a result of this indistinct signal, that the word "cat" has no coda and incorrectly store the word in her lexicon as [kæ].

Nasalization of vowels before nasal consonants in English also obscures the presence of a coda in a word like "moon", [mũn]. The child may assume that the correct representation of the word is actually [mũ], since the difference between the pronunciation of [mũn] vs. [mũ] is very difficult to hear.

Under this view, the child would alter her incorrect lexical representations when her perceptual abilities (hearing, attention span, etc.) sharpen and when she is faced with evidence that a coda must exist in a word. For example, once the child masters the plural rule, hearing the plural of a form like "cats" ([kæts]) tells the child that her representation [kæ] is incorrect since the plural of this form would be [kæz]. Thus, it must be the case that some other sound intrudes between the [æ] and the [s].

In addition, there is a generalization in English that words which end in stressed vowels (CV) must necessarily end in tense vowels (i,u,e,o,etc.). CV words that end in lax vowels (ɪ,U,ɛ,æ, etc.) are not allowed and so must be followed by a consonant. Once this generalization is understood by the child, then this would also count as evidence that [kæ] is incorrect. Finally, stress assignment in English respects whether or not syllables have codas and could provide further evidence that codas must exist in certain syllables.[5]

1.2.2 Predictions

Under this view, a child's progression from CV to CVC syllables should be uniform (similarly, in the production theory but for different reasons). This is true for the following reason: at early stages in the child's production, she will have a certain proportion of words encoded as CVC. As she gets older, she will become increasingly aware of such cues as those mentioned above. As a result, the proportion of words encoded as CVC will become steadily larger. Thus, a uniform progression is predicted overall, as at each stage a larger proportion of CVC syllables are correctly encoded.

This perceptual theory also expects that no selective avoidance will be exhibited by the child. This is true because for some amount of time the child believes she has the correct lexical representations for all her words. Thus, for the child, there is nothing "difficult" to avoid; she is not aware that her output is any different from the adult output. At such time as she becomes aware of a difference, she alters her representation accordingly. Under a purely perceptual view, the child will then proceed to output without any further difficulties.

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[4] In the following section, I am presenting one interpretation of a perceptual theory. I allow that there may be other, equally plausible interpretations available. A slight variant (proposed by Andrew Barss, p.c.) is that the child encodes an indeterminate coda for a word like 'cat', [kæQ], where Q is not identified. In this case, the child omits the coda as a result of not knowing what to put in the coda position.

[5] It is, of course, possible that some words do not get replaced until much later. This would explain what are traditionally called 'relics'. For example, the subject continued to call "Big Bear", [bibi], not because he couldn't say [bɪg ber], but because he had re-named the bear, [bibi]. Thus, his representation of "big bear" did not alter.

An additional prediction arises from the perceptual theory presented here. As stated above, misperception affects the child's representation of words in the lexicon. Therefore, under a *purely* perceptual account, once a child has correctly encoded a word as CVC, she should never produce that word again without the final consonant. Since misperception affects only the input, no other processes could alter the form on its way out of the lexicon. Thus, once the child has encoded "cat" as [kæt], she should no longer produce the word as [kæ].

A final prediction of the perceptual theory presented here directly involves a consideration of the adult input. If the adult is providing the child with cues for the proper encoding of words, then those words that the child is correctly encoding as CVC are likely to be words that are more frequent in the adult input to the child. That is, the more the child hears a word in adult speech, the more aware she should become as to whether or not that word has a coda. Thus, the more frequent CVC words in adult speech are more likely to be correctly encoded in the child's speech than less frequent words.

1.3 A Grammatical Theory

1.3.1 Properties

The final possible explanation of coda loss to be presented here is based on factors regarding the child's grammar. The basic premise is that a child produces CV syllables instead of CVC syllables in her early stages because her emerging grammar initially tells her that only CV syllables are allowed in her language. The proposed grammatical theory is based on facts surrounding language typology, the Subset Principle (Dell, 1981; Manzini and Wexler, 1987) and Parameter Theory (Chomsky, 1981; Dresher and Kaye, 1989). I discuss each of these in turn.

Greenberg (1978) made the observation that languages which have CV syllables are more common than languages which have CVC syllables. In addition, those languages which do allow CVC syllables will also have CV syllables. Within these facts lies a subset relation: languages which have CV syllables only are in a subset relationship with languages which have both CVC and CV, as shown in (2) below:

(Insert Figure 2 here)

I assume that the typology and subset relationship mentioned above reflects or is reflected in a child's acquisition of the syllable structure of her language. Given this, the existence of the above subset relation creates a possible learning problem for the child acquiring her native syllable structure.

The Subset Principle defines the steps a child takes when problems regarding subset relationships arise during acquisition. For example, suppose there are two languages, G1 and G2. G1 has property p and G2 has properties p and q. Assuming that p and q are productive properties and not constraints within the grammar, then G2 is larger than G1, and G1 is a subset of G2 as shown in (3):

(Insert Figure 3 here)

A problem arises for the child learning G1, if she incorrectly assumes that her language is actually the larger G2. This is a plausible course of action for the child, since anything in G1 is also in G2. Unfortunately, once she assumes G2, there will never be any positive evidence informing her that her grammar is actually the more constrained G1. Thus, she may make serious overgeneralizations about her language. That is, if the child assumes that property q is in her grammar, she will never hear evidence to the contrary since the adult population will not

utilize *q* in speech. The child, however, might use *q* and other properties associated with *q*. Adult input to the child informing her of her error (i.e. negative evidence) is widely believed not to have any affect on the child's grammar (Brown and Hanlon, 1970), should such input come about[6]. Thus, the child is stuck with her larger grammar.

The Subset Principle alleviates this problem. The Principle states that when a child is learning language, she automatically assumes the most constrained grammar. In the present case, then, the child learning either G1 or G2 will initially assume G1. If her language is actually G1, then she will be correct. If her language is G2, then she will expand her grammar when she is faced with positive evidence for G2.

Returning now to syllable structure, recall the subset relation that was shown in Figure 2: CV-only languages are in a subset relation with CVC/CV languages. What would happen to the child acquiring a CV-only language if she incorrectly assumed a CVC/CV language? That is, what would happen to a child that assumes the existence of codas in her language when actually none are allowed? She would be faced with a problem similar to the child who assumed the existence of property *q* above. She might make overgeneralizations, in this case, with respect to her rules of syllabification. For example, a child will allow codas where adults may epenthesize or delete a consonant to arrive at an appropriate CV structure. Such mistakes could arise during productive morphological processes or during insertion of words into the lexicon borrowed from CVC languages. That is, assuming CV syllables only, an adult would take an illicit string, for example, CV-CVC and either epenthesize, creating CV-CV-CV, or delete the final consonant, creating CV-CV, in order to form acceptable CV syllables in that language. A child with the wrong grammar (i.e. CVC/CV) would not perform either of these repairs, since she believes that CVC is an acceptable syllable type.

Also, when a child acquires language, she often imposes certain rules to make the speech production process easier. Such processes are rampant in early speech and significantly affect the types of words produced. For example, children are known to have a preference either for CV structure or CVC structure (Kiparsky & Menn, 1977). In the first case, the child might take a word like "ball", [bal], and produce it as [ba-ba]. In the second case a child might take a word like "cookie", [kU-ki] and produce it as [kUk-kUk][7]. If a child were to incorrectly assume a CVC grammar, she may produce words with this latter type of structure quite frequently during the acquisition process. This would also seriously mar her output.

Since such problems could never be eradicated with positive evidence, the Subset Principle will prevent them from arising by defining the strategy the child must take in learning the syllable structure of her language. That is, a child learning either a CV or a CVC language will initially assume she is learning a CV-only language. The details of this process incorporate the notion of parameters.

The grammatical theory outlined here proposes that when a child is acquiring her syllable structure, she must set relevant "syllabic" parameters, namely [AVOID CODA] (terminology

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[6] This is on the assumption that a child cannot learn from the absence of a property in adult speech (i.e the absence of *q*). There is, however, the notion of "indirect negative evidence" (Lasnik, 1989) which suggests that if a child assumes a property *q*, she expects to hear *q*. Over a period of time, if the child does not hear *q*, she might re-evaluate her grammar regarding that property's existence. This notion is highly debatable and I leave it for consideration in further research.

[7] Such structures as [kuk-kuk] and [ba-ba] are likely to be the result of a type of reduplication performed by the child (D. Demers, p.c.). In each case, the child reduplicates the preferred template, either CV or CVC.

taken from Prince and Smolensky, 1991). If this parameter is set to "yes", a CV language results. If [AVOID CODA] is set to "no", then a CVC/CV language results[8]. English is a language of the latter type. Thus, a child learning a language like English must eventually have her parameter set to [-AVOID CODA]. Recall, however, that by the Subset Principle, a child learning either type of language must first assume that her language only allows syllables of the type CV ([+AVOID CODA]). Thus, a child learning English will first set the [AVOID CODA] parameter to "+". When she hears positive evidence for the existence of codas, however, she will switch the parameter to [-AVOID CODA], correctly yielding a CVC/CV language.

I assume that the proposed parameter actually affects the child's rules for syllabification and that syllabification occurs (at least) prior to words entering the lexicon (recall the diagram in (1)). That is, a child's rules of syllabification will only produce CV syllables. Under this view, when a child hears a word like "cat" ([kæt]) she cannot syllabify the coda, and so the word enters the lexicon as [kæ][9].

1.3.2 Predictions

A purely grammatical theory predicts that the child should produce no CVC syllables at all (i.e. 0% coda production) in her early speech. When her parameter switches, however, she should begin to produce CVC syllables quite freely[10]. The child's progression from CV to CVC syllables, then, should reflect this change in parameter setting: there should be a sharp increase to 100% coda production in CVC syllables at some stage in her development. That is, the transition should ideally be as sharp as ninety degrees (from 0 to 100% correct coda production).

In addition, a child will not exhibit any type of selective avoidance under a purely grammatical account. Like a perceptual account (but unlike a production account), the grammatical theory does not expect the child to differentiate between CVC syllables and CV syllables at any stage in her development. That is, before the child's parameter has switched, she is presumably not aware of any differences between her output and the adult output, so there should be no difference in the proportion of CVC words attempted versus the proportion of CV words attempted. After her parameter switches, she should still attempt proportionally as many CVC words as CV words. That is, assuming that only grammatical factors are involved, once

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[8] Note that although the relevant parameter deals only with codas, another parameter would be necessary to create the correct syllable structure overall. That is, another necessary parameter is one that deals with initial consonants or onsets (e.g.[HAVE ONSET]), CV vs. V. This parameter differs necessarily from the coda parameter in that all languages are required to have onsets in all syllables or in some syllables (and therefore not [AVOID ONSET]. Codas are not required by all languages and so [AVOID CODA] and not [HAVE CODA]. The [HAVE ONSET] parameter, however, is not of crucial import here.

[9] One might argue that syllabification occurs prior to output, but this suggests that [kæt] would be correctly represented in the lexicon and be shortened on its way to production. This presents a problem in that if the word is stored with a coda, then that should be evidence that codas exist. Under this view, no coda-less words would ever be produced.

[10] There is some debate as to how much positive evidence a child must amass before her parameter switches. It seems unlikely that hearing a form only once could cause a parameter to switch, since casual errors could have a serious affect on the child. Also, children raised in bilingual households apparently do not exhibit any confusion in making the appropriate settings, even in languages as different as Hawaiian (a CV language) and English (a CVC language). It is just as difficult, however, to define how many times a child must hear a particular type of utterance before deciding to alter her parameter setting. The notion of a "counter" has been proposed, but does not solve the problem of "how many times is enough?" This is a question that any theory involving parameters must resolve.

the child knows that CVC syllables are allowed, she should produce them without difficulty. Thus, no selective avoidance is ever exhibited.

1.4 Possible Tests of the Theories

In the previous sections I have discussed three theories which might explain the coda-loss phenomenon. Each of the three theories makes certain predictions about a child's acquisition of CV and CVC syllables. The diagram in (4) makes explicit at least four possible tests of these individual predictions. I briefly explain each of these below.

(4) Predictions and Possible Tests

Predictions	Coda Production	CVCs Attempted	CVC Encoding	Frequency
Production	uniform transition	selective avoidance	-	-
Perceptual	uniform transition	no selective avoidance	once word CVC never CVC	frequent CVCs encoded 1st
Grammatical	sharp transition	no selective avoidance	-	-

First, an analysis of a child's coda production is necessary to determine the nature of her transition from CV to CVC syllables. If the data show the transition to be uniform, then the grammatical theory is ruled out. If the data show a sharp jump in the transition, then both the production theory and the perceptual theory are ruled out.

Second, an analysis of a child's attempts at CVC words versus her attempts at CV words is necessary. If the data show that the child avoids CVC syllables, then the production theory is upheld, while the other two are eliminated. If the data show the child does not exhibit selective avoidance, then the grammatical and perceptual theories are supported and the production theory is ruled out.

Third, an analysis is necessary which examines the child's use of CVC words once they are encoded as such. Such an analysis would test the relevant prediction of the perceptual theory which claims that once a child has encoded a word with a coda, she should never use that word again without a coda.

Finally, an analysis is necessary which examines the frequency of the adult usage of CVC words in speech directed to the child. Such an analysis would also test a prediction of the perceptual theory. The claim is that those words that are correctly produced as CVC by the child should be words that are more frequent in the adult input to the child than words that the child incorrectly produces without a coda.

In the following section, I discuss the results of each of the tests suggested above. First, however, I will briefly describe the subject and the data to be analyzed.

2.0 Subject

The subject, Joey, is a monolingual English-speaking child living in Tucson, Arizona. The data is taken from transcripts of Joey's speech from age 18 to 22 months. His utterances were collected and transcribed on-line in IPA by his parents, Michael Hammond and Linda Rousos. Sessions usually took place during meal or play time and were broken down by months and days. Joey's utterances were collected for a total of five months. Out of these five, he was observed on an average of 15.2 days each month. The total number of utterances (i.e. tokens) for the corpus is 357, broken down monthly as follows: 18 months:43 tokens; 19 months:110 tokens; 20 months:115 tokens; 21 months:62 tokens; and 22 months:27 tokens.

3.0 Test 1 - Coda Production

3.1 Hypothesis

This analysis of the data seeks to test the various hypotheses made by the theories with respect to Joey's overall success at the production of codas. As the diagram in (4) above shows, a "pure" interpretation of the grammatical theory predicts that there will be a sharp transition during Joey's production of syllables, from CV to CVC. This jump would reflect his change in parameter setting from [+AVOID CODA] to [-AVOID CODA]. On the other hand, both the production and perceptual theories expect the progression to proceed uniformly. Joey should have little success at producing or encoding CVC syllables in the early stages, but show increasing success with CVC syllables as he gets older.

3.2 Procedure

In this analysis, Joey's utterances were examined and all tokens that should have a coda in the adult grammar were extracted. From this "coda" corpus, percentages were calculated based on the number of times Joey correctly put a coda on a word versus the number of times he omitted a coda on a word which required one.

3.3 Results and Discussion

Figure (5) below illustrates Joey's production of CVC syllables. These results show that Joey's success at producing words with codas proceeds uniformly until, at 22 months, his successful production of codas reaches 86%.

(Insert Figure 5 here)

The results from Test 1 are most clearly consistent with either a production or a perceptual explanation of the phenomenon. Both theories predicted that a child's success at producing codas would increase uniformly. Such a uniform progression is evident in Figure 5. Joey begins by only producing 19% of his codas and steadily increases to 86% production as he gets older.

Conversely, the grammatical theory predicted an, ideally, ninety degree increase in the correct production of codas as a reflection of an altered [AVOID CODA] parameter. Were the grammatical theory correct, Figure 5 would show 0% codas correctly produced in the early stages, since only CV syllables are being produced. At some point during production, there would be a sharp jump to 100% correct codas produced, reflecting the resetting of the parameter to [-AVOID CODA]. Figure 5 reveals no such sharp transition. Thus, a "one-parameter" grammatical view is no longer a possible explanation of the phenomenon.

There is another possible interpretation of a grammatical theory, however, that might explain Figure 5. So far, the parameter proposed under the grammatical theory has only two options, either "yes" or "no". This would suggest that the choice the child must make is a discrete one. It may be, however, that there exist "sub-parameters" within (or instead of) [AVOID CODA]. That is, it is likely that when a child begins to produce codas, she will produce only a subset of those allowed in her language and those she produces may form a natural class. As she gets older, she will expand the types of codas allowed.

For example, at eighteen months, Joey may have (hypothetically) four words on which he produces a coda. The coda in all cases is either [l] or [r] (liquids), regardless of whether that is the correct coda for the word he is trying to produce. At nineteen months, he may have 10 words on which he produces a coda. The coda in these cases is either [l], [r], [p], [t], or [k] (liquids and voiceless stops). If data like this were evident, then two sub-parameters could be proposed: [AVOID LIQUID CODA] and [AVOID VOICELESS STOP CODA]. At eighteen months, Joey would set the former parameter to "no" and the latter to "yes", but at nineteen months he would reset [AVOID VOICELESS STOP CODA] to "no". This would not only more accurately reflect Joey's coda production, but would also imply that there is more than one parameter involved. It is not unreasonable to propose that such parameters exist since languages do vary in the types of codas they allow, if any. Under this revised grammatical view, the gradual increase in codas correct in Figure 5 is an illusion that masks a number of discrete jumps as the sub-parameters are reset.

3.4 Summary

Overall, the results of Test 1 do not differentiate between the perceptual or the production accounts of final consonant deletion. Both theories predicted the uniform transition in Joey's coda production depicted in Figure 5. Test 1, however, does rule out a "uni-parametric" grammatical theory as such a theory predicts a single sharp transition somewhere during Joey's production of CVC utterances. An alternative grammatical theory based on multi-parameters may, however, be able to explain the apparent uniformity of Figure 5. This revised grammatical theory would claim that Figure 5 masks a stepping effect that arises as a result of a number of parameters switching in succession. This possibility is explored below.

4.0 Test 2 - Sub-Parameters

4.1 Hypothesis

This analysis seeks to test the multi-parametric grammatical view suggested above. Two reasonable sub-parameters to suggest for English are sub-parameters based on a coronal versus non-coronal distinction (e.g. [AVOID NON-CORONAL CODA] and [AVOID CORONAL CODA])[11]. This proposal is based on the fact that the behavior of coronal codas in English syllables is markedly different from the behavior of non-coronal codas. In English, long vowels can be followed by a single consonant of any type. If a long vowel is followed by two consonants, however, the second of those consonants can only be a coronal consonant. In addition, if a long vowel is followed by three consonants, the last *two* consonants can only be

[11] In this section I only explore the possibility of two sub-parameters. Ideally, however, the greater the number of existing sub-parameters, the more plausible a stepping effect becomes. That is, more sub-parameters mean more discrete jumps being made in succession as each parameter is reset; the overall effect is a uniform transition in the correct production of codas. Future work (involving more data) seeks to explore this possibility.

coronal (e.g. "pints", /paynts/). Thus, coronal codas in English are given special status that is not bestowed on non-coronal codas. This is true in other languages as well (M. Hammond, personal communication). Given this, it seems reasonable to suggest that coronal and non-coronal codas are acquired differentially by the child.

The hypothesis, then, is that coronal sub-parameters exist and that Joey's speech may reflect a difference in their behavior. If such parameters do exist, the multi-parametric grammatical view is supported and suggests that the uniformity of Figure 5 is the result of a stepping effect and not necessarily the result of production deficits or misperception.

4.2 **Procedure**

The "coda" inventory extracted in Test 1 was utilized to explore the issue of sub-parameters. Each word that should have had a coda in Joey's speech was examined with respect to final consonant omission, substitution or correct production. Confusion matrices (see appendix) were constructed at each stage in order to illuminate a possible coronal/non-coronal pattern in Joey's coda production.

4.3 **Results and Discussion**

The confusion matrices show that Joey has a tendency to omit or substitute a glottal stop for coronal codas more so than non-coronal codas. That is, Joey is more successful at producing non-coronal codas than coronal codas. Percentages were calculated based on the number of times Joey successfully produced a required coronal coda versus the number of times Joey correctly produced a required non-coronal coda. These percentages indicate that Joey is indeed more successful with the production of non-coronal codas. Figure 6 explicates the trend in more detail.

(Insert Figure 6 here)

At eighteen months, Joey is 0% successful at producing coronal codas on words which require one, while he is 39% successful at producing required non-coronal codas. At nineteen months, Joey has gained some success at producing coronal codas, but is still better at producing non-coronal codas. Then, at twenty months, there is a marked difference in the production of coronal and non-coronal codas: Joey is only 11% successful at the coronal codas, but is 71% successful at producing the non-coronal codas. After twenty months, his success at coronal codas increases rapidly, until at twenty-two months his success at both types is approximately equal (88% for coronal codas and 85% for non-coronal codas).

These facts suggest that the [AVOID CORONAL CODA] and the [AVOID NON-CORONAL CODA] sub-parameter hypothesis may have substance. Initially, these two parameters are set at "+". The former parameter is still set at "+" at eighteen months (Joey produces 0% coronal codas correct), while the latter parameter has been switched to "-" prior to eighteen months[12]. Then, sometime after eighteen months the [AVOID CORONAL CODA] parameter also switches to "-", and success at both types of codas increases uniformly.

Unfortunately, this uniform increase constitutes a problem. A pure grammatical theory would predict instant success at the production of coronal and non-coronal codas once the parameters have been appropriately switched. That is, after both parameters are altered, Joey

[12] This is an assumption. I have no data earlier than eighteen months and so I cannot validate this claim.

should produce coronal and non-coronal codas 100% successfully. This is under the assumption, however, that these two parameters are the only two parameters active during a child's acquisition of codas. If other parameters are in effect, then they may interact with the coronal/non-coronal parameters and obscure the facts regarding the production of these types of codas. If this is true, then a multi-parametric grammatical theory continues to be a viable explanation of final consonant deletion.

A grammatical theory, however, is not the only theory that might account for the facts in Figure 6. A perceptual theory can explain the data equally well. Recall that the perceptual theory presented claims that a child misencodes CVC utterances as CV because the final C in the adult CVC signal is often acoustically indistinct. This indistinctness is especially true for coronal codas. Adults often produce coronal codas as unreleased or as glottal stops. Acoustically, there is very little information in the signal. This would predict that a child would succeed at producing non-coronal codas before coronal codas because non-coronal codas are produced with much more clarity in adult speech. This is exactly the trend that Figure 6 illustrates.

4.4 Summary

Test 2 suggests that sub-parameters exist for the child corresponding to the production of coronal and non-coronal codas. While such evidence strengthens a grammatical theory, it is not the only theory which can explain the data. A perceptual theory is also capable of explaining Joey's success at non-coronal codas over coronal codas.

At this point, it is not clear which theory is better equipped to explain the coda-loss phenomenon. The following analysis proposes to further test the perceptual theory in an effort to resolve this question.

5.0 Test 3 - CVC Encoding

5.1 Hypothesis

This analysis seeks to test whether Joey omits codas on words which he has previously produced (and presumably encoded) as CVC. The perceptual theory claims that once Joey has correctly encoded a word as CVC, he should never produce that word again without a coda. A casual glance at the data shows that this "pure" hypothesis is incorrect. For example, at eighteen months, Joey pronounces the word "that" as /dæt/. At nineteen months, he pronounces the same word as /dæ/, without the previously encoded final consonant. Because of data like this, the analysis performed here actually tests a more complex hypothesis which assumes that a child may have co-existing production problems. Co-existing production problems would allow that Joey may not always be successful at producing a CVC word once he has encoded that word correctly. If this is true, then the perceptual theory would predict that Joey should be more successful at correctly producing words with codas if he has already encoded that word as CVC once before. By the same token, he should not be as successful at producing required codas on words if he has not correctly encoded them before (i.e. these words are still CV in his lexicon) or if he has never said them before. For example, Joey should be more successful at correctly producing the word "that" again at nineteen months than he should at producing the word "cheese", which he has incorrectly encoded as CV, /tʃi/.

5.2 Procedure

At eighteen months, all tokens that Joey produced with a coda were extracted. At

nineteen months, these same words were extracted. This latter set of words was compared to his production of these utterances at eighteen months. The same procedure was used for each remaining month. Percentages were calculated based on the number of times Joey produced the previously encoded CVC word correctly.

In addition, all new CVC words that Joey produced correctly at nineteen months were extracted as were all words that he had produced before without a coda, but now produced with a coda, and so on for the remaining months. Percentages were calculated based on the number of times Joey successfully produced the "new" or incorrect "old" word. These percentages were then compared to those calculated previously.

5.3 Results and Discussion

Test 3 shows that Joey is marginally more successful at producing 'old' words correctly with a coda, but only after nineteen and a half months. Recall that the prediction here is that Joey should be better at producing codas on words that he has previously encoded as CVC. He should be less successful at producing codas on words that he has never said before or said at a previous stage without a coda. While these facts may appear to support the perceptual theory, Joey's overall success is not statistically significant. This is discussed in more detail below. Figure 7 illustrates these facts.

(Insert Figure 7 here)

At nineteen months, Joey is actually more successful at correctly producing codas on previously CV encoded utterances. At twenty months, he is 45% successful at producing previously encoded CV or new utterances. He is only 9% better at his production of previously encoded CVC utterances. The greatest difference is at twenty-one months where Joey is 24% more successful at utterances previously encoded as CVC. Despite this latter fact, the percentages show that Joey's overall success is not greater than chance. That is, three out of four times he his marginally more successful with the production of "old" words, but such odds are no better than successfully flipping a coin to heads three out of four times. These results are therefore not significant overall.

5.4 Summary

The results of Test 3 indicate that one prediction of the perceptual theory is not upheld by the data. This weakens the perceptual theory as a possible explanation of the phenomenon. Test 4 explores another prediction of the perceptual theory in order to further investigate the status of this theory.

6.0 Test 4 - Frequency

6.1 Hypothesis

This analysis seeks to test the prediction of the perceptual theory which claims that those words that Joey successfully produces with a coda should be those that he hears more frequently in the adult speech. If the adult is providing the child with cues for the proper encoding of words, as this perceptual theory assumes, then those words that the child is correctly encoding as CVC are likely to be words that are more frequent in the adult input to the child. The logic is that the more opportunities the child has to attend to the word, the more aware she should become of a word's correct structure.

6.2 Procedure

For each month, all of the utterances that Joey produced that required a coda in adult speech were extracted. These words were then divided into two lists: one list comprised all words which Joey correctly produced with a coda, and the other list comprised all words he produced without a coda. Since no adult input was available in Joey's own records, the Bernstein files from the CHILDES database (MacWhinney & Snow, 1985) were used as a generalization of the adult input to the child. The Bernstein files consist of twenty-seven observation sessions of nine different children, ranging in age from 14 to 27 months. In all sessions the mothers' input is included. For this test, all of the mothers' speech was extracted. Then, all the words from both of Joey's lists were looked up in the mothers' speech. The frequency of each of Joey's words in the adult speech was calculated. The mean frequency of the words on the first list (words correctly produced with a coda) was then compared to the mean frequency of the words on the second list (words incorrectly produced).

6.3 Results and Discussion

Test 4 indicates that there is no significant difference in the frequency of Joey's coda utterances versus his no-coda utterances in adult speech. By the prediction outlined above, those words that Joey produces with a coda should be significantly more frequent in the adult speech than those that he incorrectly produces without a coda. Figure 8 shows most clearly at 20 months that there is no difference in the frequency of words of either type in the adult speech.

(Insert Figure 8 here)

The largest difference in Figure 8 is at eighteen months where the mean frequency of Joey's utterances *without codas* is actually 10% greater than the mean frequency of his utterances with codas. This result is *opposite* from the one predicted; the perceptual theory would predict that the mean frequency of Joey's words *with codas* should be 10% greater than the frequency of those words without codas. This fact combined with the fact that all of the differences in frequency are statistically insignificant shows that this prediction of the perceptual theory is also not upheld by the data.

6.4 Summary

Overall, Tests 3 and 4 seriously weaken the perceptual theory with respect to the coda-loss phenomenon. Both tests show that two predictions of the perceptual theory are not borne out by the data presented here[13]. Each of the three theories has one remaining prediction as yet untested. These are explored in the final analysis below.

7.0 Test 5 - Coda Words Attempted

7.1 Hypothesis

This analysis seeks to test the remaining predictions of the three theories with respect to the issue of selective avoidance. The production theory predicts that Joey should avoid

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[13] An additional argument against the perceptual theory presented here is based on frequent mispronunciations such as /g (g)/ for the word "dog". This suggests that the child perceives the entire word correctly, since the final [g] is anticipated and is produced in onset position (D. Demers, p.c). This is contrary to the view here that would claim only part of the word "dog" is perceived, namely /d /.

producing CVC syllables because he is aware that the production of final consonants is difficult for him. Studies show that children do avoid structures that are difficult (cf. 1.1.2) and so Joey should exhibit selective avoidance with respect to CVC syllables. That is, Joey should attempt fewer CVC words in his early stages and uniformly increase in his attempts as he gets older and such forms become less difficult. Conversely, both the grammatical and the perceptual theories predict that Joey should exhibit no selective avoidance with respect to CVC syllables. Joey should not avoid producing CVC words at any time during his development because in both cases he is not aware of any differences between his output and the adult output.

7.2 Procedure

All utterances in Joey's speech that should have codas for the adult were extracted. Percentages were calculated based on the number of times Joey attempted a CVC word out of the total number of utterances (CVC and CV) in each monthly sample.

7.3 Results and Discussion

None of the predictions outlined above are consistent with the results of Test 5. Figure 9 shows that from nineteen to twenty-two months, Joey's attempts at CVC words proceeds uniformly. From eighteen to nineteen months, however, there is a sharp reduction in the percentage of CVC words attempted. The significance of these facts is discussed below.

(Insert Figure 9 here)

For the period following nineteen months, the production theory is consistent with the data. Joey attempts fewer CVC words early on, indicating that he is aware of his difficulty with coda production. As he gets older and this task becomes less difficult, he attempts more and more CVC syllables. The production theory, however, cannot explain the reduction in his attempts at CVC words form eighteen to nineteen months. There is no reason why Joey should find CVC syllables somewhat easier to produce at eighteen months and then find them more difficult a month later. A production theory, then, cannot account for the results of Test 5.

The perceptual and grammatical theories cannot account for the data either. Both predict a constant rate of attempts at CVC words (i.e. a flat line). That is, Joey's attempts should be consistent with the rate of attempts exhibited by adult speakers, presumably somewhere around 80% (Joey's highest percent). Figure 9 clearly does not show a flat line reflecting such constant rate of attempts.

Thus, it seems that no "pure" theory can account for the results of Test 5. Interestingly, a combination of the grammatical theory and the production theory could explain the data. A grammatical theory would predict that before the relevant coda parameter altered, there would be no avoidance of CVC syllables. Joey would be producing only CV syllables but not be aware that his output was any different from the adult's. Thus, he should make as many attempts as as an adult at CVC words, given considerations with regard to vocabulary size. After the parameter change, however, Joey should reduce the number of attempts at CVC syllables because of emerging production deficits. That is, suddenly Joey's grammar would allow CVC utterances, but he would find that CVC syllables are difficult to produce. Therefore, his attempts should be reduced. From that point on, Joey's attempts at CVC words should increase uniformly as the task of closing off the syllable becomes less difficult and he is less likely to avoid them. This is almost exactly what is depicted in Figure 9. The dip at nineteen months is expected if there

is a parameter change at 18 months. At this point, Joey is aware that CVC syllables are allowed, but he finds them difficult to produce and thus he reduces his attempts. From there on, his attempts are a reflection of production deficits[14].

This explanation of Figure 9 is the only explanation available. The other alternative is not viable; that is, no combination of the production theory and the perceptual theory could explain the data. The perceptual theory, unlike the grammatical theory, would not be able to explain the dip at nineteen months. A combination of a perceptual and a production theory would merely predict the same results as the production theory alone.

7.4 Summary

Test 5 shows that "pure" interpretations of any of the theories are not capable of explaining the data. Only a combination of a production and a grammatical theory can explain the results with any success. In fact, this combination of theories predicts exactly what Figure 9 shows.

8.0 Summary

The results of all five tests are summarized in Figure (10) below. A "yes" response indicates that the particular theory was consistent with the results of that test. A "no" response indicates that the particular theory was refuted by that test. A "-" means that the particular theory made no claims with respect to that test.

(10) Summary of Test Results

Theories	Test 1	Test 2	Test 3	Test 4	Test 5
Production	yes	-	-	-	no
Perceptual	yes	yes	no	no	no
Uni-parametric grammatical	no	no	-	-	no
Multi-parametric grammatical	yes	yes	-	-	no
Unified production/ grammatical	yes	yes	-	-	yes

9.0 Conclusion

On the basis of the facts summarized in Section 8, it is clear that an explanation of coda-loss based on any single theory is inadequate. A strict or "pure" conception of any of the

[14] An interesting possibility is that the "dip" in Figure 9 is correlated with the "dip" in Figure 6 (Test 2 - coronal/non-coronal sub-parameters). That is, it may be possible that the dip in Figure 9 reflects the altering of the [AVOID CORONAL CODA] parameter. This analysis has been undertaken, however, and shows no correlation between the two.

explanations given cannot explain the data presented here. The most logical solution to this dilemma is to recognize that these theories are not mutually exclusive. Test 5 clearly shows that both the production and the grammatical theories are necessary. The perceptual theory, however, is seriously weakened by the results of Tests 3, 4 and 5. While the perceptual theory still remains as an alternative explanation of Tests 1 and 2, either of the other two theories can explain the data equally well. Thus, there is no reason to assume that the perceptual theory plays any role at all in the coda-loss phenomenon. I maintain this argument for the data presented here, but given that perceptual problems are known to play a role in other language acquisition domains (Bower, 1977; Stern, 1977), it is possible that future research of this phenomenon will illuminate the necessity for some form of a perceptual theory. Overall, then, I have argued for the necessity of a unified production and grammatical theory to account for final consonant deletion in early child speech. I propose, in conclusion, that the grammatical theory constrains the child's input to the lexicon based on operative syllable parameters. Once these parameters have been altered, the child's output is constrained by production deficits. Further research involving additional data is necessary to determine the exact nature of these syllable parameters.

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FIGURES

(2)

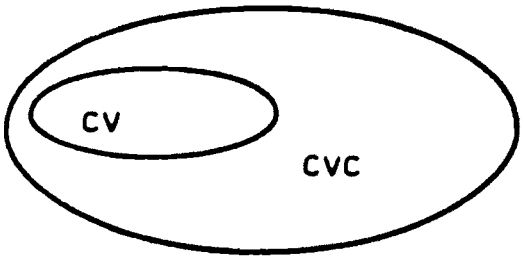


FIGURE 2

(3)

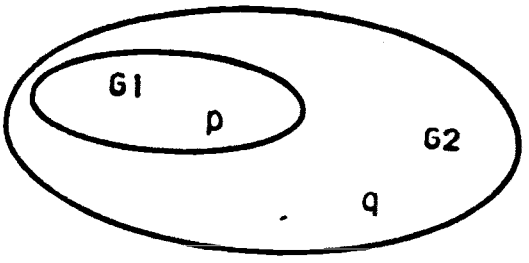


FIGURE 3

(5)

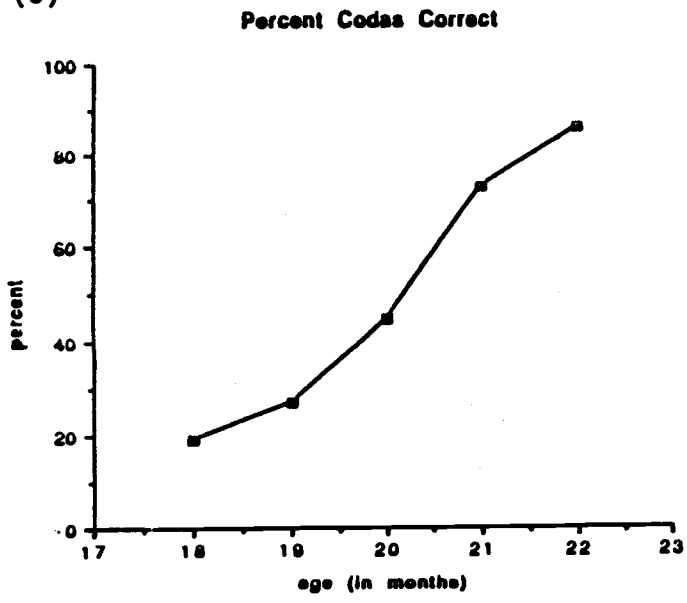


FIGURE 5

(6)

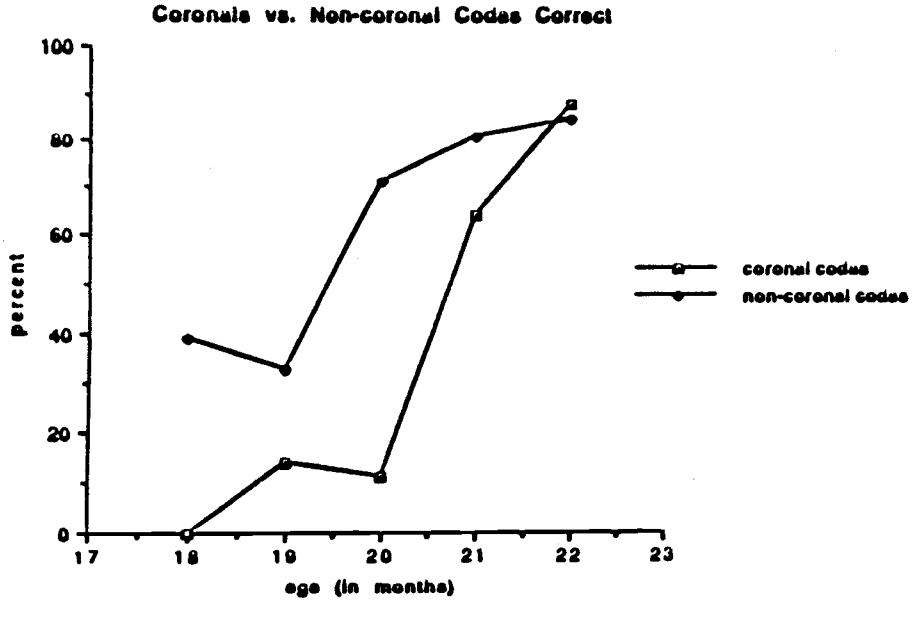


FIGURE 6

(7)

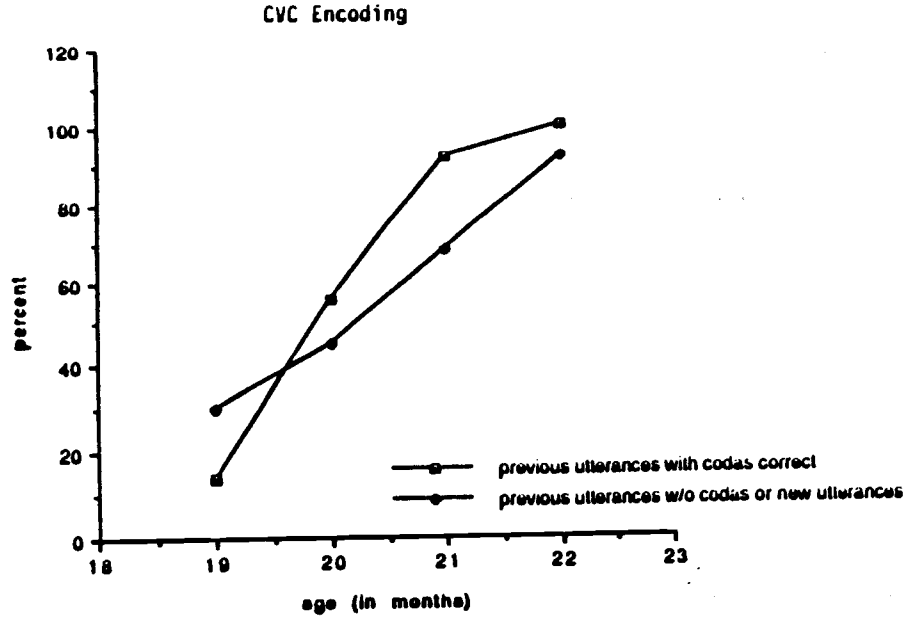


FIGURE 7

(8)

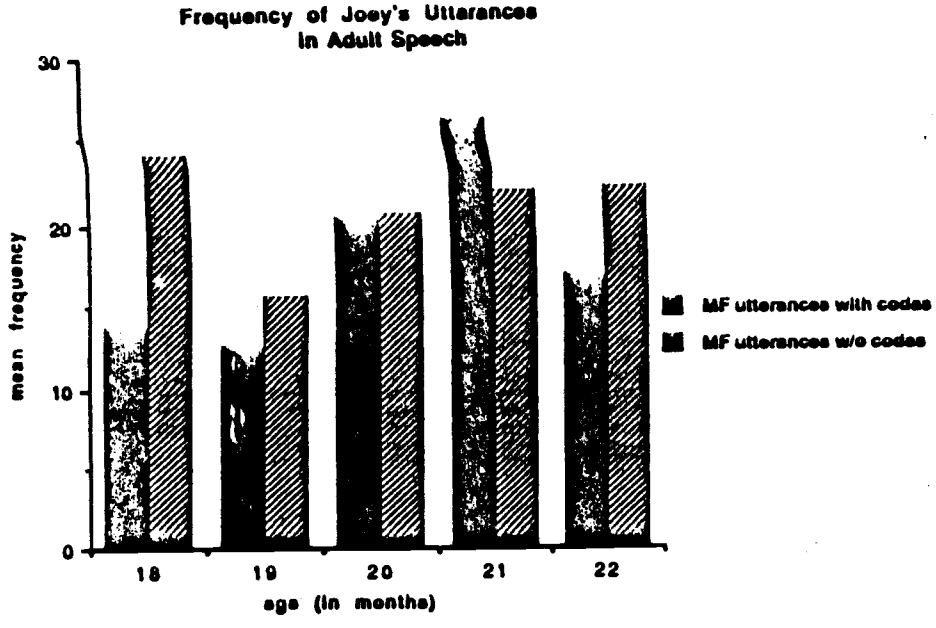


FIGURE 8

(9)

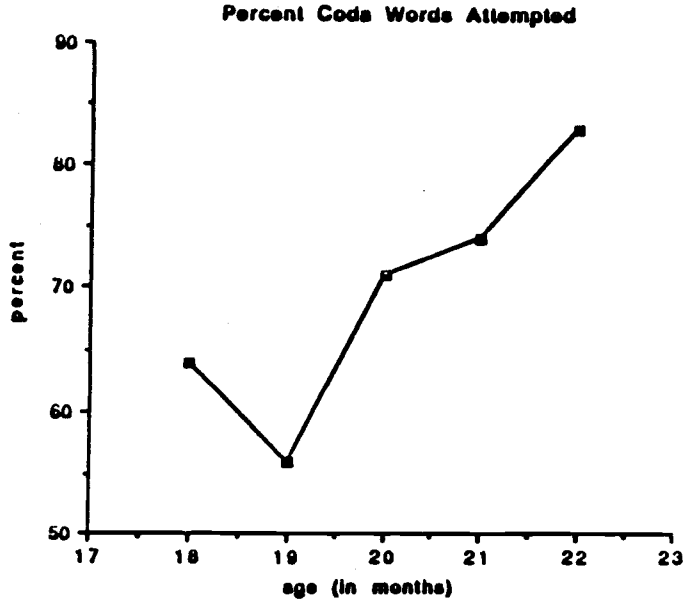
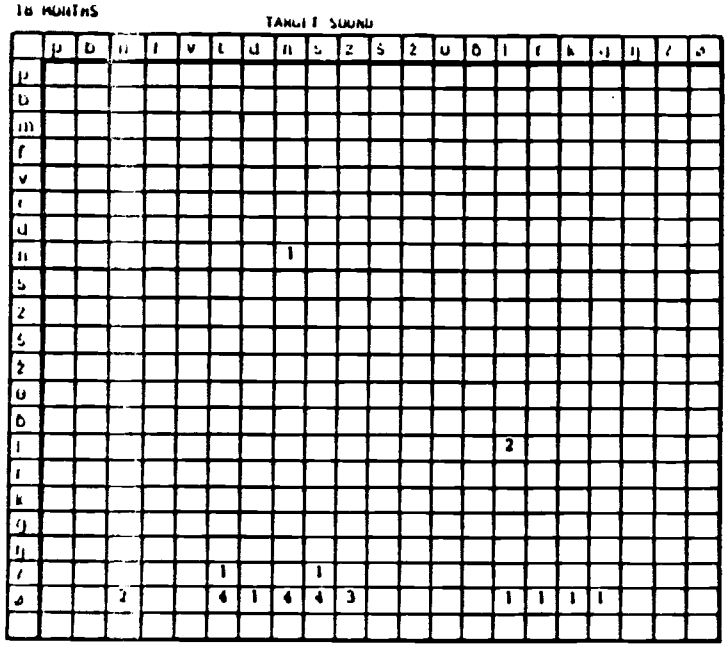
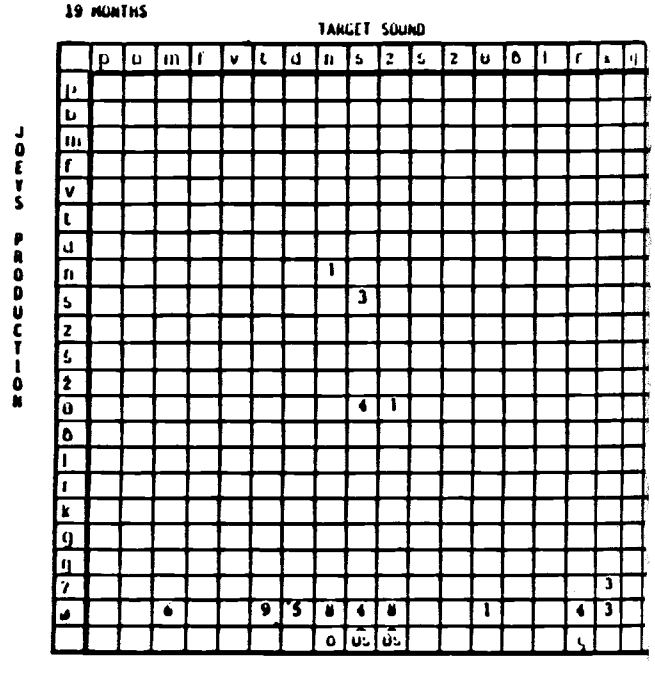


FIGURE 9

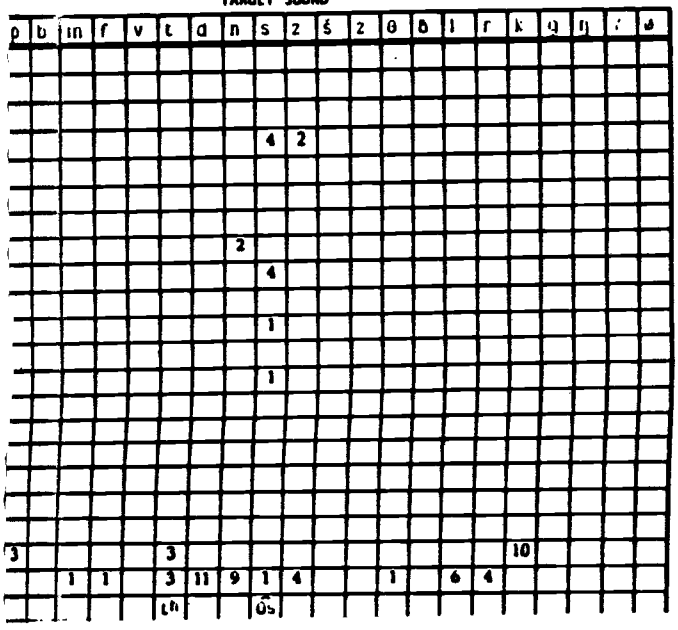
APPENDIX CONFUSION MATRICES





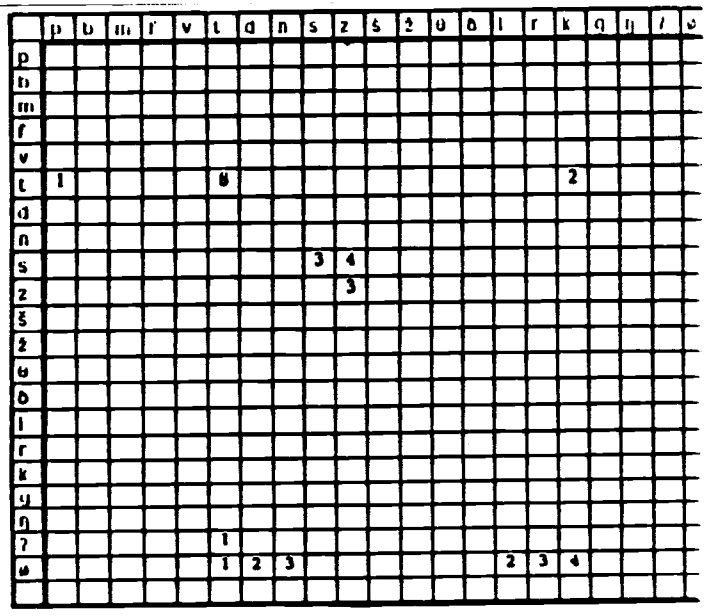
MONTHS

TARGET SOUND



21 MONTHS

JOINT PRODUCTION



MONTHS

TARGET SOUND