Variable Productivity: Evidence from the English Lax Vowel Constraint

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1. **Introduction**

1.1 Overview

The productivity of the English Surface Phonetic Constraint which forbids the occurrence of a lax vowel word finally is tested by means of a number of experimental techniques, in order to ascertain whether apparent rule productivity varies in accordance with the particular criteria adopted: borrowing; memory for nonsense forms; a syllable-division language game; and pluralization tasks including both recognition and production.

The results of the experiments reported in section two demonstrate that there exists a methodological difficulty for claims about rule productivity: productivity tests do not all give the same results. For example, speakers make very few errors in repeating nonsense words ending in the disallowed lax vowel, yet no borrowings into English retain a final lax vowel from the source language. In addition, this research has some bearing on the usefulness of the tense/lax distinction for English vowels in such producitivity testing.

1.2 Rule Productivity and Psychological Reality

In the opinion of many linguists, constructing a psychologically real grammar for a language involves more than simply capturing all possible generalizations since a linguistic description does not necessarily reflect the implicit or explicit knowledge of the speaker (e.g., Innes 1974). In order for linguistics to be more than just "a discipline of arbitrary formal taxonomies" (Derwing 1979:209), a theory must be supported by psychological evidence demonstrating that the linguist's generalizations match the speaker's knowledge. That is, an analysis of natural speech can only provide a description of the regularities which appear therein, but cannot determine whether all such regularities should be represented as rules of constraints operating in the speaker's internalized grammar.

1.3 Rule Productivity

The application of a phonological rule or constraint to novel (nonsense) forms has been taken as evidence that the speaker does in fact have access to the content of the rule in question (e.g., Berko 1958). Productivity tests have been used in the past to demonstrate the psychological reality of various phonological rules and regularities.

The extent to which alterations are made to words borrowed by one language from another can demonstrate the productivity of rules which adjust the foreign word to fit the patterns of the borrowing language. Rules of the native language of a language learner have been shown to cause adjustments in his pronunciation of words in the target language; these errors together make up what we call a foreign accent (Kenstowicz and Kisseberth 1979). Language games can produce nonoccurring sequences which may be modified to fit the sound patterns of the language (Sherzer 1970). These modifications provide evidence for the "productivity and psychological reality of the phonological rules and constraints operation in the language" (Kenstowicz and Kisseberth 1979:162).

Rule productivity can also be tested by eliciting responses from subjects or by asking them about what is acceptable in their language. In Berko's (1958) study she elicited plural forms of nonsense words to test the productivity of the regular pluralization rules of English. Messer (1967) tested the productivity of Surface Phonetic Constraints by asking subjects for their judgments as to which of a pair of words sounded more like a possible English word.

All of these methods have been employed to determine the productivity and psychological reality of a rule or regularity.

1.3.1 Borrowings

Borrowed words are a good source of evidence for the application of rules and constraints. For example, data from borrowings suggest that there exists an optional rule in many varieties of English which changes a [d] or [t] to a flap [ɾ] when it occurs intervocalically after a stressed vowel (Schane 1973). There are many examples of words which have a [t] or [d] in the relevant position in a source language and are pronounced with a flap when borrowed into English. Consider certain Spanish words which contain an intervocalic /t/, for example: *Don Quixote* [doŋkix'ote], *matador* [matad'or].[1] These items have undergone the flapping rule (and in the latter case a stress shift) in their borrowed form, and thus follow the pattern of English: [dɒŋkiy'oɾiy] and [m'æɾədɔr]

1.3.2 Foreign Accents

A rule's productivity can also be judged by observing the types of errors made by people learning to speak a foreign language. Speakers of a given language background tend to make the same phonological errors when learning the same second language. In accordance with the contrastive analysis hypothesis (Wardhaugh 1970), these errors result from interference from the speaker's internalized L_1 grammar; the combination of these errors is what listeners perceive as a foreign accent (Kenstowicz and Kisseberth 1979).

1.3.3 Language Games

Language games where speakers are required to change the form of words, thereby creating novel forms to which the putative rules may or may not apply, provide additional insights into the speaker's grammar. If a word is altered such that it no longer follows the patterns of the language, the player has the option of applying phonological rules to normalize the new form.

Sherzer (1970) reports that the Cuna Indians of Panama have a word game called Sorsik Sunmakke (talking backwards) in which the first syllable of a word is moved to the end of a word. For example, the word [mola] *cloth* would become [lamo]. This game provides evidence for the productivity and psychological reality of a regularity in which voiceless stops are underlyingly represented as voiced geminate consonants.

1.4 Experimental Manipulations

A somewhat more direct approach to testing rule productivity is to ask subjects to pronounce or manipulate either nonsense forms or real words with potential violations of the constraints of the language. For example, Berko (1958) tested children's knowledge of English pluralization rules by asking them to pluralize nonsense words such as *wug*, *gutch* and *heaf*.

While children performed very well on real words such as *glass*, they did less well on nonsense words such as *tass*; Berko interpreted this as evidence that a child may internalize plurals individually without developing a (productive) rule for novel forms.

1.5 Surface Phonetic Constraints and the English Lax Vowel Constraint

1.5.1 Surface Phonetic Constraints

In this study we shall be examining the differential effects of several experimental techniques in testing the productivity of a Surface Phonetic Constraint of English. Surface Phonetic Constraints (hereafter SPC's) describe the possible and impossible combinations of phonetic features at the phonetic level. They are the rough equivalent in a generative grammar of phonotactic rules in a structuralist grammar which delineate the possible words in a language by determining the phonological sequences which may occur.

Shibatani (1973) proposed SPC's as part of a generative grammar in order to account for constraints which apply at the phonetic level and whose application domain is the word. Previously, the grammar relied upon Morpheme Structure Conditions together with the effects of phonological rules to capture phonetic constraints but Morpheme Structure Conditions apply at the morphophonemic level and only within a morpheme. Shibatani states that certain alternations (such as the plural inflectional ending) can only be explained with SPC's because the application of the constraint is across a morpheme boundary.

1.5.2 The Lax Vowel Constraint

The SPC examined in this study is the one which prohibits the occurrence of a lax vowel at the end of a word in English. This is not a universal constraint since there are word-final lax vowels in other languages, for example, French: *Français* [frãsɛ].

This particular constraint was chosen for study since it would appear that it is not as strong a constraint as others (e.g., the aspiration rule); a quick survey of a few speakers showed that although [pɪk] (without initial aspiration) was difficult to imitate—all speakers either aspirated the /p/ or changed it to a /b/—there was no difficulty with nonsense words such as [skɛ] or [flɪ].

Sapir (1933) discussed the lax vowel constraint and the reactions of his students when they encountered words which violated it. When his phonetics students transcribed a non-English word ending in a lax vowel, they tended to hear and transcribe a glottal stop at the end of the word. They did not, however, transcribe a glottal stop after tense or unstressed vowels (e.g., schwa). When asked to repeat these words, they did so in a "drawling fashion" (p. 59).

Sapir points out that English allows only three word endings: tense vowel or diphthong; tense vowel or diphthong plus consonant(s); and lax vowel plus consonant(s). He proposes that the students had normalized non-English words ending in lax vowels. By "drawling" the lax vowel they presumably created an acceptable word-final diphthong, and addition of the glottal stop "serves as the actualization of a phonologically required final consonant .... The illusion of the final glottal stop is essentially the illusion of a generalized final consonant needed to classify the words into a known category" (p.59); lax vowel plus consonant. The mistaken addition of the glottal stop is not as common in the transcription of words ending in an unstressed lax vowel. This is presumably due to the fact that some English words end in unstressed lax vowels, such as *sofa* [s'ofə] and *Canada* [k^h'ænədə].

The reactions of Sapir's students thus demonstrate that the lax vowel constraint operates at the end of words, but Sapir also suggests that it operates at syllable boundaries. In the following passage, Sapir makes reference to type C and type D word classes. These are, respectively, words ending in a lax vowel plus consonant, and words ending in a lax vowel:

> "Observe that the apparent inconsistent possibility of a nonfinal accented syllable ending in a short vowel (e.g., fiddle, butter, double, pheasant) is justified by the English theory of syllabification, which feels the point of syllabic division to lie in the following consonant (d, t, b, z, in the examples cited), so that the accented syllables of these words really belong phonologically to type C, not to type D. Intervocalic consonants like the d of 'fiddle' or z of 'pheasant', in spite of the fact that they are not phonetically long, are phonologically "flanking" or two-faced in that **they at one and the same time complete one syllable and begin another.**" (p. 59) [emphasis added]

Sapir's observation, although based on intuition, is rather interesting. The case of intervocalic consonants occurring after a lax vowel poses a dilemma for syllable division: should the consonant be used to close the syllable so as to avoid a final lax vowel? Or, should it be placed in the next syllable in accordance with our intuitions about syllable division? Is there any empirical support for Sapir's claim that the consonant serves both functions? If so, does this mean that such consonants are in some sense underlying geminates? (See section two for data in support of Sapir's view.)

The view that syllables with stressed lax vowels always end in a consonant is supported by the syllable divisions found in several English dictionaries: in *Webster's Seventh New Collegiate Dictionary* (1965), the two pronunciations of the word *Babel* were divided into syllables as follows: [b'e$bəl] and [b'æb$əl] (where $ = syllable boundary). In the first pronunciation, the first syllable contains a tense vowel and is left open; in the second pronunciation, the first syllable contains a lax vowel and it is closed.

Whether the editors of the dictionaries are actually aware of a theoretical constraint on syllable division based on the lax vowel constraint, or whether they make intuitive judgments is unclear, but the fact remains that dictionary methods of syllabification (in the sources consulted) do not violate the constraint.

Another source of evidence supporting the view that the final lax vowel constraint operates on syllables within the word is a surface structure constraint in English which dictates that a stressed vowel must be tense when occurring before another vowel, for example, *variety* [vər'aiəti] and *pious* [p'aiəs] (Moskowitz 1973). Since a vowel is in syllable-final position if it occurs immediately before another vowel, the lax vowel constraint is supported.

1.6 Direction of Normalization: Borrowings, Foreign Accents, and Naive Orthographers

1.6.1 Borrowings

If the lax vowel constraint is productive, then speakers of English, when faced with a foreign or novel (nonsense) word ending in a stressed lax vowel, should normalize these words to follow English phonological patterns. Evidence from borrowed words suggests that this normalization is realized by changing the lax vowel to the corresponding tense vowel. For example, the following French words all end in a lax [ɛ]; they have been borrowed into English with a tense final vowel:

French		**English**	
baie	[b'ɛ]	[be]	*bay*
ballet	[bal'ɛ]	[bæl'e]	*ballet*
gourmet	[gurm'ɛ]	[gʊrm'e]	*gourmet*
toupet	[tup'ɛ]	[tup'e]	*toupee*

1.6.2 Foreign Accents

The same tensing change is made by speakers of English learning to speak another language; they tend to pronounce all final vowels as tense, even though they may be lax in the target language. For example, French words ending in [ɛ] are pronounced with a final [e] by English students, and Russian words with a final lax [ɔ] are pronounced with a tense [o].

Such evidence not only suggests the direction in which English speakers will normalize any word which breaks the constraint, but also demonstrates that the constraint is productive.

1.6.3 Naive Orthographers

Another reason to believe that English speakers will tense final lax vowels is provided by the naive orthographers studied by Read (1971). Read examined the spelling systems invented by children as young as three and one-half years. These children first learned the conventional names of the letters of the alphabet, then used blocks with letters to spell words before learning grapheme-phoneme correspondences. The children studied by Read all arrived at approximately the same spelling system. They used a given vowel symbol to represent both a tense vowel (letter names for a,e,i,o,u) and the corresponding lax vowel.

For example, the letter *A* [e] is used to represent the [e] in *day* and the corresponding lax vowel [ɛ] as in *fell* [fɛl]. The following are some typical invented spellings (pp. 6, 7, 10):

A		[e]			[ɛ]	
	DA	*day*	[de]	*FALL*	*fell*	[fɛl]
	KAM	*came*	[kem]	*LAFFT*	*left*	[lɛft]
E		[i]			[ɪ]	
	EGLE	*eagle*	[igəl]	*FES*	*fish*	[fɪš]
	FEL	*feel*	[fil]	*FLEPR*	*flipper*	[fl'ɪpr̩]

These naive spellers thus recognize a relationship between tense and lax vowels.

The evidence from the naive orthographers, borrowings, and foreign language students as well as the fact that specific pairs of tense and lax vowels enter into phonological alternations in other languages leads us to believe that these vowels are closely related phonetically, and enable us to predict that the productivity of the lax vowel constraint involves changing a word-final lax vowel to the corresponding tense vowel (just as the productivity of the aspiration rule results in the aspiration of unaspirated initial voiceless stops).

Two other possible changes would be the addition of a glottal stop after a lax vowel (cf. Sapir's students); and lengthening or diphthongizing the lax vowel (e.g., [dɛ] would be pronounced [dɛʔ], [dɛa], or [dɛ:]).

1.7 Variable Productivity

Whorf (1956) presents a structural formula which will generate all of the monosyllabic words of English as well as possible but non-occurring English words. Whorf states that:

> "...by the time the child is six, the formula has become ingrained and automatic; even the little non-sense words the child makes up conform to it, exploring its possibilities but venturing not a jot beyond them. At an early age the formula becomes for the child what it is for the adult; **no sequence of sounds that deviates from it can even be articulated without the greatest difficulty.**" (pp. 223 ff.) [emphasis added]

Whorf's view is that it is extremely difficult to break morpheme structure rules (or SPC's) and pronounce a word which cannot be generated by the formula.

Messer (1967) conducted an experiment to test whether children can discriminate between monosyllabic words which are possible according to Whorf's formula and words which are not. He presented children between the ages of 3;1 and 4;5 with pairs of words, one of which could be generated by the formula and one which violated it. The children were asked which sounded more like a word or which better described an object.

Messer found a significant tendency in his subjects to choose the words predicted by the formula. Moreover, in a repetition task, the children made minimal changes to individual phonemes so as to render the words more English-like. Messer thus demonstrated that children's speech is governed by the structural formula even at a very young age. One purpose of the present study, then, is to discover whether the pronunciation of all words which violate the formula is as difficult as Whorf suggests.

Another experiment which demonstrates that non-English sound sequences are more difficult to pronounce was conducted by Paula Menyuk (1968). She presented children between the ages of 4;5 and 8;3 with pictures and names, some of which were possible English words and some of which contained consonant sequences which are not grammatical for English but are possible in other languages. The children were required to point to the picture to which the name applied (having heard the names associated with each of the five pictures), to repeat each name after it was pronounced by the experimenter, or to repeat the five names after the whole set had been presented. In all tasks the response time was greater for the ungrammatical names and in the reproduction tasks the children had much more difficulty in reproducing the ungrammatical sequences. This study also supports the view that non-English sound sequences are more difficult to pronounce for English speakers.

Brière (1968) studied difficulties English speakers have in overcoming phonological interference in learning to pronounce sounds from other languages. He had his subjects listen to and repeat a tape recording of words containing non-English sounds. After each repetition, the subjects were given instructions on how to produce the sound and they were told which English sounds it was comparable to. Two of the sounds tested were [ŋ] and [ž] in initial position. The subjects found [ŋ] to be much more difficult to pronounce in initial position than [ž], even though [ŋ] has a considerably higher frequency in English. In discussing this study, Moskowitz (1973) proposes that,

> "... it may be that the low frequency of the fricative plus the high frequency of the velar nasal with respect to the morphological processes to which it is psychologically connected, cause this result: namely that the phonotactic restrictions on the fricative can be violated with greater ease. It is doubtful that any speaker of English, despite an ability to produce word-initial [ž] is not aware of its non-English sound." (pp. 250-251)

In other words, Moskowitz claims that English speakers are aware that [ž] is not a native English sound, and thus have less difficulty moving it to a new position because it is already slightly foreign.

Another explanation for the difference in the ease of breaking SPC's is that English speakers make an analogy between the word and the syllable. Since [ž] is permissible in syllable-initial position, as in *measure*, it is not as difficult to position it at the beginning of a word as is [ŋ] which never occurs at the beginning of a syllable (dictionary editors may not show that [ž] is permissible syllable-initially via the invalid argument that it does not occur word initially). This latter hypothesis seems to be a less complex explanation than the former.

The relative ease with which SPC's for vowels can be broken has not been investigated. It is our hypothesis, however, that SPC's for vowels will be more easily violated than those for consonants. For example, some English paralinguistic utterances contain final lax vowels (e.g., *baa baa* [bæ] *blacksheep*), but none contain initial unspirated stops or initial /kt/ clusters. We propose that there will be a continuum of productivity varying from borrowings in which the constraint is one hundred per cent productive, to imitation, in which the constraint is not productive. Furthermore, if the tense/lax distinction is not a uniform phenomenon with regard to productivity tasks, it may be the case that the constraint is more likely to apply to some vowels than to others.

Further evidence that task demands may affect apparent productivity comes from the study done by Menyuk discussed above. Menyuk obtained different results in production and perception tasks when testing children's responses to grammatical and nongrammatical phonological sequences. When the children simply had to memorize a set of names corresponding to five coloured circles, the ability to learn and remember the set generally increased with age.

When the children were asked to repeat the set of names, the results were quite different. There were no children who could correctly reproduce an ungrammatical set of five words. The number of children who could repeat a grammatical set varied at each age level with the oldest children doing slightly better than the preschool children. Thus, as Menyuk concludes, the data from the production tasks fails to reveal the differences in learning abilities at given age levels which appear in the recognition tasks. In other words, "the child reveals one aspect of his competence when he produces utterances on demand, in accordance with linguistic rules, and another when he recognizes correct usage of these rules." (Anisfeld and Tucker 1967:1202). The different types of tasks seem to involve different aspects of the child's competence.

Similarly, Anisfeld and Tucker (1967, discussed below) found different results in recognition and production tasks involving children's pluralization ability not only in the level of difficulty (which is what usually distinguishes the two methods) but also in the pattern of errors. "The two procedures were seen to have tapped different aspects of the S's linguistic knowledge " (p. 1216).

Since some rules are more productive than others and since experimental method can affect the apparent productivity of a rule, we will be testing the productivity of the lax vowel constraint using a variety of experimental techniques. Thus both the application of the rule and the effectiveness of the methods will be tested.

1.8 English Phonotactics and Pluralization

The knowledge of English pluralization rules provides a good testing ground for the lax vowel constraint. Methods previously employed by Anisfeld and Tucker (1967), Berko (1958), and Messer (1967) to treat children's knowledge of the pluralization rules and SPC's of English will be used in this study to test the subject's knowledge of the lax vowel constraint. We will be employing the production tasks described in the Berko and Anisfeld and Tucker studies, and the recognition tasks from the Anisfeld and Tucker and Messer studies.

In the production task of Berko's experiment, a child was shown a picture of one figure and given its (nonsense) name. The experimenter then presented a picture of two of the figures and asked the child to produce the name pluralized. For example,"*This is a wug. Now there is another one. There are two of them. There are two ....*" (p. 155).

Anisfeld and Tucker criticized Berko's use of the numeral before the blank, suggesting that it provided extra information and that a better understanding of the child's knowledge might be gained by having him produce the singular form once he has been given the plural and vice versa. Anisfeld and Tucker used both singular and plural formation rules in their tasks. In their recognition tasks, they provided the child with a picture of one figure and two names, asking the child to choose the best name; two pictures (one figure and two figures) and one name, letting the child choose the picture to which the name applied; and two pictures and two names asking which name referred to which picture.

Messer used methods similar to those of Anisfeld and Tucker to test the children's knowledge of SPC's on consonants. He also simply asked subjects to choose the form which sounded more like a word.

All of these methods will be used to test for our adult subjects' knowledge of the lax vowel constraint. For example, a subject may be asked which of two pictures shows [pɛz]. If the subject chose a picture of two figures it would appear that the lax vowel constraint was not applied since the singular form (minus the /-z/ plural marker) would violate the constraint and would not be a grammatical English word (*[pɛ]).

1.9 Summary

The existence of the lax vowel constraint has been supported by Sapir's writings and shown by the methods in which dictionaries divide words into syllables, borrowings, and foreign accents. Adjustments made by English speakers to words that end in lax vowels are expected to be in the direction of tensing the lax vowel as predicted by the close relationship found between tense/lax pairs found in other languages and the spellings of naive orthographers.

Rule productivity tests have been done in the past by such people as Messer, Sherzer, Moskowitz, Menyuk, and Brière and it has been found that different rules may not be equally productive and that different methods can yield different results.

Although Whorf claims that SPC's cannot be broken without greatest difficulty, we expect that the lax vowel constraint is not hard to break and its productivity will vary with experimental methods.

2. Experiments*

2.1 Introduction

The hypothesis that different methodologies might lead to different conclusions regarding the productivity of the lax vowel constraint (LVC) was tested by comparing adult subjects' performance on a variety of experimental tasks. In each case, the data of interest include the **degree** to which subjects avoid final lax vowels (in terms of the percentage of items normalized), the particular **strategies** used, and the **direction of normalization** (e.g., tensing, "drawling," insertion of glottal stops, reduction to schwa, etc.).

The tasks include **repetition,** which presumably taps immediate perceptual categorization as well as production ability; **memorization,** which reduces immediate memory effects and allows subjects to reconstruct the final vowel (this is intended as a rough analogy to the foreign accent phenomenon); **a syllable transposition** task which can "strand" lax vowels in word-final position (e.g., river /vɚ́ rɪ/); and three **picture labelling** tasks involving a choice between possible and impossible plurals (e.g., /spez/ vs. /spɛz/) and between singulars and plurals (e.g., singular /skɛz/ or /skes/ vs. plural /skez/). In the latter case, performance on picture-naming tasks involving final *-l*, *-n*, and *-r* stems (e.g., /pɛlz/ vs. /pɛls/) serves as a baseline for determining whether the technique is appropriate for tapping knowledge of at least some SPC's on pluralization.

2.2 Experiments[2]

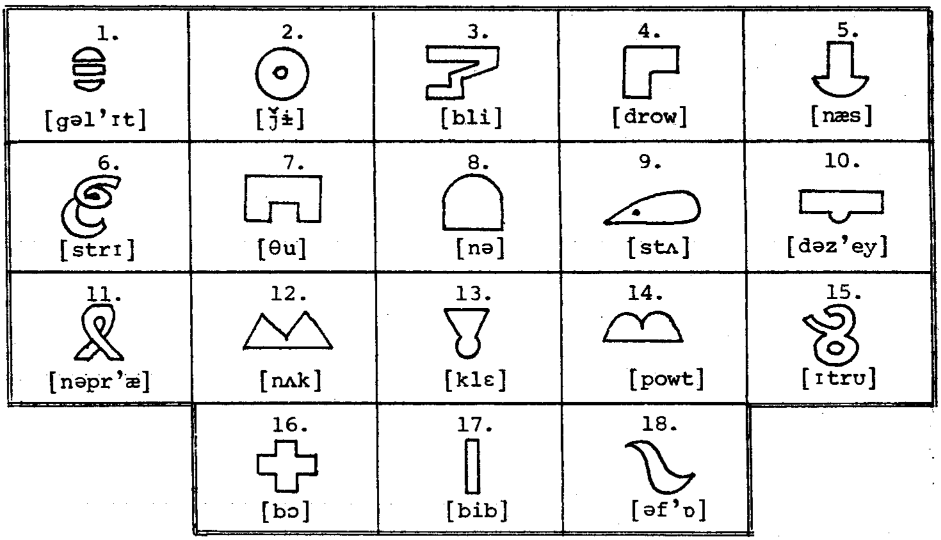
2.2.1 Pilot Studies

The **repetition** and **memorization** tasks were administered in informal pilot studies in order to determine whether the lax vowel constraint would have any effects worth pursuing.

In the **repetition** task, five adults and one 3-year old child were asked to repeat 18 nonsense words as picture names including 8 ending in [ɨ], [ɪ], [ə], [ʌ], [æ], [ɛ], [ʊ] and [ɔ] (see Figure I). Each name was presented by the experimenter in a sentence frame (e.g., *This is a ....* or *This looks like a ....*). The adults were able to repeat almost every name as they heard it. It was noted that alterations were made in some lax vowels as follows: [ɨ] → [ɪ], [ə] → [ʊ], [ɛ] → [ʌ], [ʊ] → [u] and [ə], and [ɔ] → [ə]. The other lax vowels were repeated correctly. The child, who was given the test three times, made a great number of changes including: [ɛ] → [ə] (3 errors); [ɪ] → [ʌ] (3 errors); [ʊ] → [ə], [ʌ] (3 errors); [ɨ] → [ɪ], [ə] (3 errors); [ɔ] → [o] (1 error); [ə] → [ʌ] (1 error); [ʌ] → [ə] (1 error); and [æ] → [ɑ] (1 error). The child made at least one error in each of the lax vowels but made no errors in repeating words ending in tense vowels or consonants nor did the adults.

Figure I

NAMES AND PICTURES FOR PILOT STUDIES



(Some of these figures were adapted from the film "Shared Nomenclature," Ohio State University, 1972.)

The general conclusion to be drawn from this initial attempt is that although the LVC is, as we saw in section one, as "regular" as other SPC's of English, and equally powerful as a condition on the phonemicization of borrowed words, it does not afford the native speaker the kind of difficulty suggested by Whorf. However, knowledge of the constraint—even if attributable to incidental learning—may be tapped by examining error rates (e.g., are there more errors on final lax vowels?) rather than normalization data. Rank orderings or error rates could provide a better basis on which to claim that there exists a behavioral correlate to LVC.

One problem with the task is that the experimenter may not have pronounced the word identically for all subjects. This was remedied in later experiments by recording and monitoring all stimuli and responses on audio tape. Also, subjects were screened for foreign language experience.

The pilot study for the **memorization** task involved only one subject. He was asked to memorize the name of the objects presented in Figure I, and was asked to recall them three hours later. The subject was observed to use mnemonic strategies, perhaps due to the large number of items. For examply item 16, [bɔ], was remembered as the first part of *buoy* [bɔy]. Since the subject obviously was not storing these words as they were presented to him (with a word-final lax vowel), we cannot see clear reconstruction effects for the ungrammatical words.

In the revised memorization experiment, each subject wwas presented with a smaller number of items to memorize. Secondly, the names and pictures were altered so as to make an association with an existing object more difficult. For example, the subject found that the picture of item 6, [strɪ], looked like a piece of string, and learned the name as "*string* minus *-ng*." Lastly, the names were purposely constructed so as to suggest to the subject a connection with the English meaning. This decreased the range of mnemonic strategies available to subjects. For example, [stæ] provides the consonant cluster *st-* to connect the nonsense word to its English meaning ***nest***.

2.2.2 Experimental Tasks

The tasks in Experiments 1, 2, 3, 4, 5, and 7 were administered in a single 45-minute session for each of eight adult subjects. The six tasks were presented in different orders for each subject.

2.2.2.1 Experiment 1: Repetition

The repetition task was presented first to all but the first subject. Since the task involved repetition of non-English nonsense words, it was thought that the subject should have had no previous experience with final lax vowels to ensure that his first attempts at repetition would be naive.

Subjects: The eight male subjects were Engineering students at The University of Calgary. All were between the ages of 19 and 23 and all were known to the experimenter and participated in the experiment on a voluntary basis. All were native speakers of English with limited knowledge of other languages, and none reported any hearing or speech problems.

Materials: Ten sentence frames were composed for the target nonsense words (e.g., *This is called a* /wʌ/), and each frame was used for two items, for a total of 20 test sentences.

The nonsense items were monosyllabic or disyllabic words; seven ended in consonants or consonant clusters and the remaining thirteen ended in vowels, either lax or tense (where these terms are meant to distinguish between the vowels which are and are not subject to LVC). The nonsense words were positioned at the end of the sentences in order to ensure that final vowels would not be affected by subsequent articulations.

Each of the 20 sentences described a brightly colored picture of a cartoon animal presented on a four-inch by five-inch file card. The sentences and pictures were shown to all of the subjects in the same order.

Procedure: The first seven subjects were tested for all six tasks individually in a quiet room. Their voices and the voice of the experimenter were recorded on a Sony TC-580 reel-to-reel tape recorder in order to allow for monitoring of any variation in the stimuli received by the subjects, and to allow for later transcription of the responses. The eighth subject was tested for all six tasks in a quiet hallway and his responses were recorded on paper. Each subject was first questioned about his previous linguistic experience.

The instructions pointed out that the nonsense names and pictures were "silly" because they were to be used in experiments with young children (see section three for discussion on this point). The subjects repeated each of the twenty sentences while looking at the picture it described. This task lasted approximately two minutes.

Results: The raw score data from Experiment 1 is found in Table 1. Exact repetitions are marked with 'R'; changes from the experimenter's pronunciation are transcribed. The vowel [ɨ] was deleted from the analysis, since, on the basis of the recordings, the experimenter doubted her ability to produce the vowel consistently. Percent correct repetition by vowel is shown in Table 2.

A two-way analysis of variance was performed with factors Percent Correct (C) collapsed across subjects and Syllable Structure (SS) (final consonant, lax vowel, or tense vowel). The overall F was significant ($F(2,18) = 5.17$, $p < .05$), indicating that either or both of the factors had an effect. Examination of all means reveals that the errors

Table 1

RAW SCORES OF REPETITION

WORDS	SUBJECTS							
	1	2	3	4	5	6	7	8
[tɒ]	R	R	R	R	[a]	R	R	R
[næǰ]	R	R	R	R/	R	R	R	R
[swɛ]	R	R	R	R	R	R	R	R
[bud]	R	R	R	R	R	R	R	R
[wʌ]	R	R	R	R	[ə]	R	R	R
[pæ]	[a]	R	R	R	[æ]	[æ]	[ɑ]	R
[kli]	R	R	R	R	R	R	R	R
[ðɛst]	R	R	R	R	R	R	R	R
[flʊ]	[ə]	[ə]	[ʊə]	[ə]	R	R	R	R
[bəd'o]	R	R	R	R	R	R	R	R
[θər]	R	R	R	R	R	R	R	R
[vɔ]	[ə]	[ə]	[ə,o]	[o]	[ə]	[o]	R	[ə]
[gæŋk]	R	R	R	R	R	R	R	R
[fu]	R	R	R	R	R	R	R	R
[sɪ]	R	R	R	R	R	R	R	[i]
[dorl]	R	R	R	R	R	R	R	R
[če]	R	R	R	R	R	R	R	R
[sprə]	R	R	R	R	R	R	R	R
[šɛk]	R	–	R	R	R	R	R	R

Table 2

PERCENT CORRECT REPETITION BY VOWEL

Vowel	**% Correct**	
[ɔ]	12.5	
[ʊ]	50	
[æ]	50	prohibited word finally
[ʌ]	87.5	
[ɪ]	87.5	
[ɒ]	87.5	
[ɛ]	100	(not permitted word finally)
[i]	100	
[o]	100	
[u]	100	permitted word finally
[e]	100	
[ə]	100	

were almost entirely attributable to **lax** vowels (66.7% correct vs. 95.8% correct for tense vowels and 100% correct for consonants). A separate analysis of variance with factors Subjects (S) by Syllable Structure again shows a significant effect of SS, ($F(2,14) = 49.00$, $p < .01$), but no significant subject differences ($F(7,14) = 2.14$, $p > .05$). We can thus conclude that in repetition, alterations are most likely to be make to **lax** vowels in word-final position, as predicted by the lax vowel constraint.

Discussion: In spite of the low overall error rates, the results support a repetition difficulty difference between vowels which may and may not occur word finally: only one vowel which is allowed in word final position, [ɒ], showed any errors at all; at 87.5% correct (7/8 correct, with one [ɑ] rendition) it does not pattern very differently from the 100% correct scores attained by **all** of the vowels normally occurring in that position. This is in sharp contrast to the spread of 12.5 to 100% for the lax vowels. This wide spread is rather interesting, for it suggests that the lax vowels cover a broad range of repetition difficulty, while the tense vowels and [ə] all show nearly perfect performance (note that [ɛ] is 100% correct). The notion of a difficulty ordering is worth pursuing; however, one should not be surprised if the ordering revealed in this task is less sensitive than one would wish, due to apparent ceiling effects. Finally, the few changes that can be discerned do **not** follow from a tensing prediction. Instead, we find /ɔ/ change to /ə/ or /o/, /ʊ/ to /ə/, /æ/ to /ɑ/, /ʌ/ to /ə/, and /ɒ/ to /ɑ/.

2.2.2.2 Experiment 2: Syllable Division

Subjects: The subjects tested in this experiment were the same as those in Experiment 1.

Materials: The word list for the syllable transposition task consisted of 51 items. Seventeen of the items were real English words; the remaining 44 were nonsense words, none of which violated the SPC's of English. The words were all disyllabic and varied not only in terms of phonemic content, but also in stress pattern, number of consonants in initial, medial, and final position, and tenseness of the first vowel (which was to be moved to word-final position).

Procedure: The subjects were tested under the same conditions as in Experiment 1. This task was presented to the subjects as a language game, similar to the familiar Pig Latin. Subjects were read the instructions which asked them to switch the order of the syllables in each word (e.g., birdhouse-housebird). The experimenter then presented the items in Word List 1.

It was discovered in an informal pre-test that subjects may adopt a strategy of dividing the word before a single medial consonant, but also place a copy of that consonant at the end of the newly created word (e.g., *river* /vɚ -rɪv/). If such a strategy was adopted by a subject, this was pointed out by reading a standard explanation after the 26 items of List 1. (This turned out to be necessary in every case.) Subjects were then read new instructions which altered the task such that the experimenter would read the original word, then say the first syllable of the "game" word (e.g. *river*, *ver*......). The subject was to complete the new word by adding the first syllable of the old word. The rest of the list was treated in this way. The purpose of this task was to note whether subjects would allow a word to end in a lax vowel when the syllable division was indicated by the experimenter; alterations to final vowels would then suggest difficulty in breaking the lax vowel constraint.

Results: The subjects' responses are given in Table 3, categorized by the type of syllable division performed. Column I, headed V/C, indicates a division between the first vowel and the medial consonant:

Table 3

EXPERIMENT 2: RAW SCORES BY SUBJECT

	(I) V/C	(II) ¢	(III) C/C	(IV) C/V
Word Type 1 **- V C V -** **[-tns]**				
n'æfɪsk	7	0	0	0
b'ɪvi	4	2	0	1
g'ɛpɒr	4	4	0	0
f'æzəl	3	4	0	1
r'ʊlʌp	1	6	0	0
d'ɛsɪŋ	2	6	0	0
w'ɪbət	6	2	0	0
ð'æfəc	7	1	0	0
z'æšəm	6	2	0	0
p'ʊkey	7	1	0	0
t'ʊgəθ	7	1	0	0
θ'ɪfəst	7	1	0	0
bət'æd	5	3	0	0
nɛvər	2	5	0	1
pl'ɛžər	3	5	0	0
r'ɪvər	7	0	0	0
s'ʊti	7	1	0	0
prəd'us	8	0	0	0
v'ɪdəm	2	6	0	0
Word Type 2 **- V C V -** **[+tns]**				
l'eygɔr	4	3	0	1
f'imo	8	0	0	0
s'ʌləp	1	7	0	0
r'onij	7	1	0	0
p'ɒgən	5	3	0	0
m'udən	6	2	0	0
'ošən	4	3	0	0
p'epər	6	2	0	0
st'ʌmək	5	3	0	0
k'ɒpi	6	2	0	0
bik'ʌm	8	0	0	0

	(I) V/C	(II) ¢	(III) C/C	(IV) C/V
Word Type 3 **-VCCV-**				
g'ɪltək	0	2	6	0
g'æstow	0	3	5	0
p'olfæz	1	0	7	0
vədr'ɪs	5	1	1	0
s'ɛldəm	0	0	8	0
'onli	0	0	8	0
bl'ɪstər	2	2	3	1
fɔrg'ɛt	0	0	8	0
Word Type 4 **medial affricates**				
y'ɛči	0	8	0	0
h'ʊǰəp	4	4	0	0
pəǰ'ɪk	2	5	0	1
Word Type 5 **medial -r-**				
č'ɔrəg	1	4	0	3
k'ɔrəz	0	3	0	5
sm'ɔrɒk	4	4	0	0
l'ɔrɪt	3	5	0	0
fərbon	4	3	0	0
g'ɔri	0	4	0	3
Word Type 6 **medial -ŋ-**				
j'ɒŋər	0	4	0	4
m'ɛŋɛr	0	3	0	4
Other				
ʌfr'ed	8	0	0	0
w'eygən	4	4	0	0

e.g., v'ɪ/dəm → d'əmvɪ. In the case of words ending in a lax vowel, such a division places the vowel in word-final position, and alterations may be examined. Column II, headed ∅ , indicates use of the **consonant copying strategy**: e.g., v'ɪ∅əm → **d**'əmvɪ**d**. Column III, C/C, is relevant only for words with medial consonant clusters, and indicates division between the two consonants (e.g., g'æs/tow → t'owgæs). However, such items may also, alternatively, be treated as V/C (e.g., st'owgæ), ∅ (st'owgæs), or even as Column IV, which was intended to represent divisions such as f'æz/əl → 'əlfæz.

When the copying strategy was first observed, it was assumed that this was a special strategy for avoiding final lax vowels, and it was expected that the C/V column would contain a preponderance of items as /v'ɪdəm/ → /dəmvɪd/. However, Table 4 shows that this is not the case.

Table 4

DISTRIBUTION OF RESPONSE TYPES BY VOWEL TENSENESS

Vowel Type	V/C	∅	C/V	Total
Lax	64.2%	33.8%	2.0%	100%
Tense	47.3%	41.7%	11.0%	100%

The strategy applied to both types of final open syllables, and there seems to be a greater tendency to close syllables ending in a tense vowel. Thus, the results do not support the hypothesis that final lax vowels will more often be subject to the syllable-closing strategy.

Table 4 also demonstrates that the most frequent response type is in fact one in which the syllable is left **open** word finally (V/C), in accordance with a syllable division leaving the medial consonant at the beginning of the second syllable. The three exceptions to this division are [ɛ], [ʌ], and [ɔ], all of which are subject to the lax vowel constraint. This seems to offer some support to the notion that the restricted vowels are subject to the "non-final" constraint. However, other vowels subject to the constraint, [ʊ] and [ɪ] pattern with the tense vowels in allowing more open syllables.

Table 5 presents the percentage of times each vowel was left in an open syllable. When the vowels are placed in a rank order according to the amount of responses which left each vowel in an open syllable, there does not seem to be a clear distinction between tense and lax vowels, but rather a progression in the ease with which a vowel can be left in an open syllable, although there does seem to be a greater concentration of lax vowels at the lower end of the scale.

Table 5

PERCENTAGE OF RESPONSES IN OPEN SYLLABLES BY VOWEL

Vowel	Percentage Open Syllables	Vowel	Percentage Open Syllables
[ɛ]	34	[o]	73
[ʌ]	37	[æ]	74
[ɪ]	53	[u]	75
[e]	62	[ə]	81
[ɒ]	69	[i]	100
[ʊ]	71		

When a subject is warned against using the copying strategy, what does he do? Table 6 suggests that the syllable-closing tendency is difficult to overcome, reducing from 46% to 31.5% syllable divisions; the V/C division prevails: all of the reduction in ₵ responses, as well as all C/V responses become V/C.

Table 6

PERCENT RESPONSES BY RESPONSE TYPE BEFORE AND AFTER INSTRUCTIONS TO AVOID ₵

	V/C	₵	C/V	Total
Before	39.0	46.0	15.0	100
After	68.5	31.5	0	100

This experiment was also designed to examine alterations made to lax vowels when placed in word final position by the game rule. Overall, lax vowels were altered in some way only 18% of the time when they occurred word finally; tense vowels were always pronounced accurately. This again suggests that the tense/lax distinction appears only as a rather weak effect on error rates. This alteration took many forms:

some lax vowels were raised (e.g., [ɛ] → [ɪ] one occurrence); some were tensed (e.g., [ɔ] → [o] six times), [ʊ] → [u] three times, and [ɛ] → [e] once); some were lowered (e.g., [ʌ] → [ɒ] twice); some were centralized (e.g., [ʊ] → [ə] and [æ] → [ʌ] once each); and some were given an offglide (e.g., [ɪ] → [ɪ^əy] twice, and [ʊ] → [ʊ^ʔ] once). Overall, there was no consistent pattern to changes in the lax vowels.

Discussion: This experiment gave mixed results concerning subjects' use of LVC. On the one hand, the final lax vowels were not altered in any theoretically relevant ways, and the syllable-closing strategy was neither excessively nor even principally applied to word-final lax vowels. On the other hand, the only vowels which were altered in production were those subject to the lax vowel constraint. The results can be explained in a general way in terms of the following English syllable-structure tendencies:

(a) medial consonants begin the second syllable,

(b) word-final syllables are closed (cf. Sapir 1933).

Although one is tempted to propose a third strategy:

(c) word-final lax vowels are disallowed

such a strategy is subsumed by strategy (b). The fact that medial consonants always belong with the following vowel, regardless of whether the preceding vowel is tense or lax, runs counter to the practice of the editors of English dictionaries, who avoid breaking syllables so as to leave a lax vowel in syllable-final position. In fact the data show a slight preference in this experiment for subjects to leave most vowels in open syllables! At any rate, we find here no behavioral correlate to the descriptively useful tense/lax distinction as regards internal syllable division. It would appear that the syllable structure strategies outlined above are more salient to the English speaker than the weaker LVC.

Sherzer (1970) did not report any use of the consonant copying strategy in Sorsik Sunmakke. He simply provided sample words from the game which would shed light on questions he had put forward. He gave examples like *saban* → *bansa* and *sapan* → *bansab* as evidence that voiceless stops pattern as consonant clusters, but did not state whether this strategy was used 100% of the time by these speakers or whether the consonant copying found in the current experiment was ever used (e.g., *saban* → *bansab*).

The lesson to be learned from this task is that not all productivity tests will tap underlying knowledge. Whereas Experiment 1 provided evidence that the constraint plays a role in repetition, Experiment 2 provides no such evidence in terms of restrictions on syllable structure. In addition, it is fortunate that **both** tense and lax words were examined in the copying strategy: although the [vɚ-rɪv] phenomenon seemed to be a very convincing argument to the effect that English speakers avoid open syllables ending with lax vowels, this is seen to be only a consequence of a broader tendency to close all syllables word-finally. The fact that the strategy was adopted at all and by every subject supports Sapir's flanking theory.

One question which remains unanswered is whether such results demonstrate anything about the strength of English LVC in comparison with other types of rules. For example, if the results of a similar experiment in some lesser known language had shown a powerful effect (a definite preference for the ₵ strategy for lax vowels, much higher rates on lax vowel endings, and consistent normalization of lax to tense vowels), no one would have been surprised. After all, there is independent evidence that LVC is productive (borrowings, foreign accents), that language games reveal interesting facts about phonological processes (e.g., Scherzer 1970), and that the tense/lax distinction has some psychological validity for English speakers (Moskowitz 1973; Read 1972). The status of the syllable in phonology and the process of syllable division are far from being well understood. While this experiment has inadvertently served as a demonstration of this fact, it has also revealed a number of interesting tendencies which may suggest some directions for further research.

Words with medial /ŋ/ had a unique pattern of syllable division. Although fifty percent of these items were divided after the [ŋ], (e.g., mɛŋɚ → ɚ́mɛŋ), all other cases were treated as C/C—as though the original word had contained /ŋg/: /mɛŋɚ/ → /gɚ́mɛŋ/. Since there is no [g] in the stimulus word, this may be a spelling effect. However, it is equally possible that the medial /ŋ/ represents an underlying /ng/ sequence (see, for example, Fromkin 1975 for such an analysis). One step toward resolving this issue would involve having illiterate (but otherwise normal) English speaking adults, as well as pre-literate children, attempt the game. The fact that the subjects never divided words with medial /ŋ/ **before** the [ŋ] is probably due to its distribution in English: it never occurs word- or syllable-initially. This is of special interest in the present study, since such a restriction is quite analogous to the lax vowel constraint: lax vowels never occur word- or (at least according to dictionary editors) syllable-finally. Why then, the difference in the strength of these two constraints? One might speculate that there is a fundamental difference in the articulatory difficulty in producing disallowed sequences of vowels and consonants (just as **sgtlzk* is more difficult than *æ*io*ʊʌɪɑ*u*), or perhaps that the lax vowel constraint is **not** in any performance-related way a syllable structure constraint after all, but only a word-structure constraint. If one argues that lax vowels are permitted in internal syllable-final position (e.g. /rɪ-vɚ/), then the analogy to word-final position would make the constraint much easier to break. One must also consider the possibility that the constraint is not linguistically significant (e.g., it does not enter into any morphophonemic alternations), and is thus nothing more than an accidental pattern in the language—one which might be accidentally learned.

Another interesting pattern emerges in the items *afraid* and /vədr'ɪs/. These were the only two items with medial consonant clusters which were rarely divided as C/C. Possible explanations for this lie in the stress patterns and the particular consonant clusters involved. The only other word in the list which had stress on the second syllable was *forget*, which was treated as C/C. The difference between *forget* and the above two words lies in the consonants which make up the cluster: [dr] and [fr], the consonant clusters in the two atypical items both occur word-initially in English wereas [rg] does not. This fact might result in a tendency to keep these consonants together as a cluster. However, two other items, *blister* and /g'æstow/, contain permissible initial /st/, yet were divided between consonants 8 times out of 15. Perhaps, then, the shift in stress to the final syllable somehow brings about greater cluster cohesion. However, the data are too sparse to justify such a conclusion at this point. Nonetheless, it would not be difficult to expand this task so as to include a greater variety of clusters and a balanced number of stress patterns in order to test this hypothesis property.

A third point of interest involves a number of times which were divided phonetically rather than phonologically. In two words which involve progressive assimilation, the assimilation appears in the created word even though the two interacting sounds had been separated by the transposition rule. For example, two subjects (one not included in the reported data) divided the word [rõnɨǰ] between the [o] and the [n], yielding [nɨǰrõ]. Even though the vowel no longer immediately preceded the nasal, it was still nasalized.

Four out of eight subjects divided the word *wagon* between the /æ/ and the /g/. In normal pronunciation, the /æ/ is partially assimilated to the /g/ by an offglide: [wæʸgən]. Two of the four subjects kept the offglide on the /æ/ even though it has been separated from the /g/.

These irregular divisions could, perhaps, be explained by assuming that subjects sometimes operate on surface representations—that is, that phonological rules are sometimes applied before the syllable division. On the other hand, it is possible that some phonologically predictable variants such as the [æʸ] have different degrees of perceptual salience either across allomorphs, across listeners, or both. Either of these speculative solutions would account for these results, but it is unclear to what extent speakers and phones can vary in this way.

Another interesting result is that 65% of the medial affricates which fell in the ₵ column were split into a stop plus either a fricative or an affricate. For example, [y'ɛči] was split as both [šiyɛt] and [čiyɛt]; [h'ʊǰəp] was divided as [ǰəphʊd]; and [pəǰ'ɪk] was changed to [ǰɪkpəd]. This pattern could be attributed to orthographic influences (e.g., *yet/chy*). To control for this, here again it would be useful to have both illiterate adults and pre-literate children attempt the task. Such results are obviously relevant to the enduring question as to whether [č] should be represented as one segment or as two ([tʃ]) (Fromkin 1975).

Finally, in two of the English words, the subjects clearly used orthographic cues to determine the pronunciation of the new word. In the words *produce* [prəd'us] and *afraid* [əfr'ed], the changed words became *'duce-pro'* [duspro] and *'fraid-a'* [fredæ]; the final vowels are both apparently spelling pronunciations.

2.2.2.3 Experiment 3: Memorization

Subjects: The subjects in this experiment were the same as those in Experiment 1.

Materials: A list of 13 monosyllabic, vowel-final nonsense words was compiled for the subjects to memorize as "foreign" words. Each nonsense word was paired with a common English word which served as its gloss. The English words were all concrete, highly imageable nouns, some of whose meanings or phonetic content helped in recall of the nonsense words (for example [stæ] and its gloss *nest* share a consonant cluster; the consonant of [zɒ] is the sound made by its gloss *bee*. These intentional memory aids were included in order to reduce the time it took the subjects to learn the words, and to impose some limits on the mnemonic strategies subjects were likely to use. Since it was only the quality of the vowel which was being monitored, mnemonic strategies involving the initial consonants were not expected to interfere with the results.

The nonsense words consisted of an English consonant or consonant cluster followed by a tense or lax vowel.

Procedure: The testing was done under the same environmental conditions as in Experiment 1. The tape recorder was on throughout the memorization process so that all of the subjects' attempts at the nonsense words would be retained. This task took about fifteen minutes to complete.

The experiment consisted of four parts. In Part I, the experimenter read both the nonsense words and the corresponding English words, asking the subject to repeat after her. In Part II, the experimenter read through the list of nonsense words in random order asking the subject to recall the English glosses. This procedure was repeated until the subject could give all or most of the English meanings. In Part III, the experimenter read the list of English words in random order and asked the subject to supply the nonsense word. The learning criterion was one perfect trial. Part IV was the final test, which took place twenty-five minutes later, after several intervening tasks. In this task, the subject was asked to provide the appropriate nonsense words when given the English words in random order. This final test took approximately one minute.

Results: Analysis of the memorization results was divided into three parts. The first part involves subjects' repetition of the experimenter's pronunciation of the nonsense words during the initial learning trials. Percent correct repetitions out of the total number of attempts at the nonsense words were calculated for each vowel and are presented in rank order in Table 7.

Table 7

PERCENT CORRECT REPETITION, EXPERIMENT 3

Item	Percent Correct	
kʊ	52	
nʌ	60	
bɔ	67	
stæ	71	ALL DISALLOWED WORD-FINALLY
lɪ	73	
mɨ	74	
zɒ	96	
shɛ	96	
gri	100	
pru	100	ALL PERMITTED WORD-FINALLY EXCEPT [ɛ]
dre	100	
flə	100	
stro	100	

As can be seen from Table 7, there is a fairly clear difference in repetition success between vowels which may and may not occur word-finally. Only [ɛ] is misclassified; as in Experiment 1 [ɛ] is rendered more accurately than the other vowels subject to the constraint. Although more sophisticated techniques could be brought to bear on a larger amount of data, it seems quite clear that repetition errors are fairly predictable on the basis of the phonotactics of the vowel in question: vowels subject to LVC rank lowest in terms of percent correct repetition.

The percentages of correct attempts during the learning trials were also calculated for each vowel, and these are presented as a rank order listing in Table 8. Although there were very many mistakes in this section, and although they were largely due to the fact that the subjects had simply not yet learned the items, predicting error rates on the basis of the tenseness of the final vowel misclassifies only /zɒ/, which misses the "permissible in final position" category by only one rank.

Table 8

PERCENT CORRECT RECALL, EXPERIMENT 3
LEARNING TRIALS

Item	Percent Correct	
nʌ	25	
mɨ	29	
bɔ	30	ALL DISALLOWED WORD-FINALLY EXCEPT [zɒ]
shɛ	31	
stæ	31	
kʊ	37	
zɒ	40	
lɪ	52	
dre	56	
flə	68	
gri	72	ALL PERMITTED WORD-FINALLY
pru	78	
stro	100	

The final test results were analyzed according to the percentage of the subjects who provided the correct nonsense word, and once again the rank order was calculated as in Table 9, and again only one item, /lɪ/, is miscategorized on the basis of a tense/lax prediction.

The difficulty orderings for the vowels in the first part and the final test of the experiment were compared by a Spearman's Rank Correlation Coefficient analysis. A positive correlation was found between the two orders ($r_s = 0.86$, $z = 2.98$, $p < .01$) confirming a consistent difficulty ordering for memorization and pronunciation.

Table 9

PERCENT CORRECT RECALL, EXPERIMENT 3
FINAL RECALL TASK

Item	Percent Correct	
kʊ	12.5	DISALLOWED WORD-FINALLY
stæ	37.5	
nʌ	7.5	
bɔ	37.5	
mɨ	50	
shɛ	50	
dre	50	PERMITTED WORD-FINALLY EXCEPT [lɪ]
zɒ	62.5	
lɪ	62.5	
gri	75	
pru	87.5	
stro	100	
flə	100	

The average rank order for the two data sets (repetition and recall) as shown in Table 10 is as follows: [ʊ], [ʌ], [ɔ], [æ], [ɨ], [ɪ], [ɛ], /[ɒ], [i], [u], [ə], [o]. Notice the clear grouping of lax vs. tense vowels: those vowels which are prohibited in word-final position are ranked 1 through 7, while those permitted in word-final position are ranked 8 through 12.

Finally, a few comments are in order regarding the direction of normalization; the distribution of responses is shown in Figure II. In the repetition portion of the experiment, only /ɔ/ followed the tense/lax prediction: 3 out of 7 alterations were to /o/. The vowel /æ/ drifted toward /ɒ/, /ɑ/, and /ʌ/ (backing), /ɨ/ drifted toward /i/-/ɪ/ (fronting), the vowel /ʌ/ migrated toward /ɑ/, /ə/, and /ɛ/, and the vowels /ʊ/, /ɔ/ and /ɪ/ showed a trend toward /ə/ substitution. In the final memorization task, the errors were somewhat scattered across the vowel chart. One would require much more data and more sophisticated cluster analyses in order to make sense of this spread.

Table 10

AVERAGE OF RANK ORDERS FOR REPETITION
AND FINAL RECALL TASKS
EXPERIMENT 3

Item	Mean Rank Order	
kʊ	1.00	
nʌ	2.50	
bɔ	3.00	
stæ	3.50	DISALLOWED WORD-FINALLY
mɨ	6.00	
lɪ	6.75	
shɛ	7.00	
zɒ	7.75	
dre	8.50	
gri	10.50	
pru	11.00	PERMITTED WORD-FINALLY
flə	11.00	
stro	11.80	

Figure II

DISTRIBUTION OF RESPONSES FOR FINAL RECALL TASK: EXPERIMENT 3

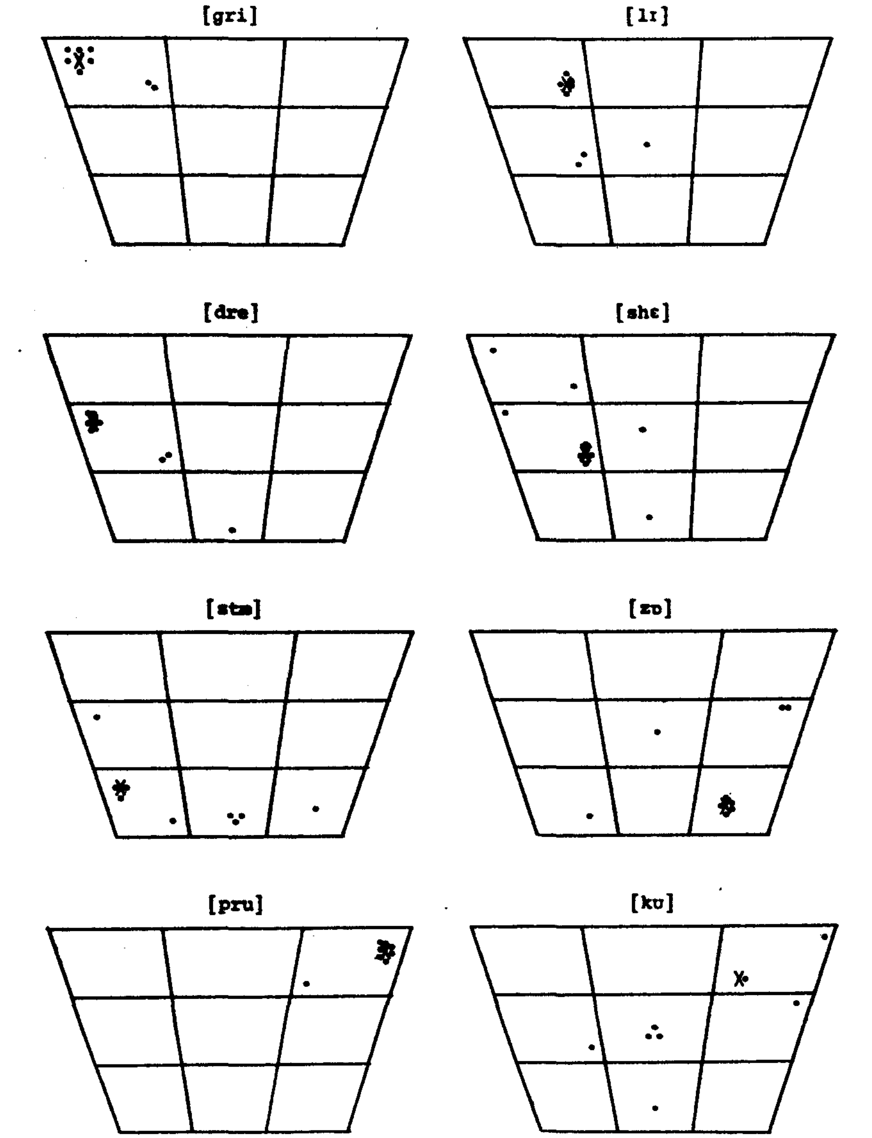
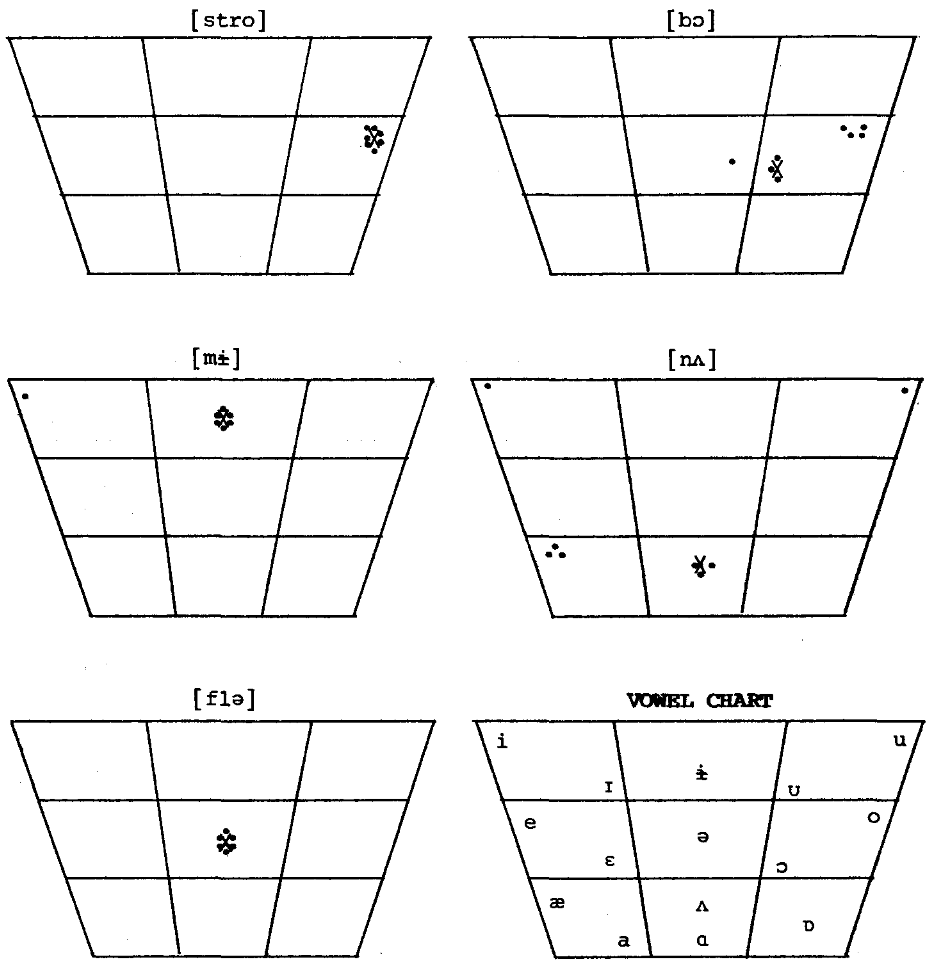


Figure II

(cont'd.)



Where, X = target vowel, and

• = subjects' attempts at target vowel

Discussion: Each sub-task in this experiment again revealed that error rates are consistently ranked in terms of LVC: those items which violate LVC have the greatest error frequencies. However, the data are insufficient to allow one to discover patterns in the alterations to such vowels. It may be of interest to pursue the study of recall errors in such a task in order to determine whether the errors reflect the types of miscategorizations found in studies of vowel perception (e.g., Assman, Nearey and Hogan 1982). Such a result would have implications for both types of results: in vowel perception studies, vowels are often presented in isolation; if the English SPC prohibiting the occurrence of such stimuli as **words** has an effect on vowel perception, miscategorizations should be similar to those found in the present. However, the converse argument may also be advanced: *a priori* constraints on vowel perception/categorization may fully explain the results of the present study (or a greatly expanded memorization task).

2.2.4 Experiment 4: Picture Labelling
(Two Words, One Picture)

Subjects: The subjects in this experiment were the same as in Experiment 1.

Materials: The 30 pictures used in this experiment were colorful cartoon drawings of people and of real and invented animals. Half of the four-inch by five-inch file cards depicted only one figure and the other half showed two.

The test words consisted of 30 pairs of items; some were existing English words, corresponding to the pictures of people and real animals, and the rest were monosyllabic nonsense words (all of which conformed to the SPC's of English) matched randomly with one- or two-figure cards.

The test list was a random mixture of 30 pairs of words from seven sets. The first set contained three "singular" words ending in sonorants (r, l, n) and their "plurals" ending in /-z/ (e.g., [/pɛl/-/pɛlz/). The second set contained four words ending in tense vowels or diphthongs plus their regular plural forms (+/-z/) (e.g., /sti/-/stiz/). Set 3 consisted of five pairs in which the first member ended in a sonorant (r, l, or n) plus /-s/ and the second member ended in the sonorant plus /-z/ (e.g., /pɛls/-/pɛlz/). Set 4 (two pairs) distinguished between singular and plural on the basis of voicing agreement after tense vowels rather than sonorants (e.g., /skes/ (sg.) -/skez/ (pl.). Set 5 consisted of the crucial items to be used for testing the lax vowel constraint. It involved seven pairs of words, both of the words of the form C(C)Vz, in which one member contained a lax vowel and the other a tense vowel (e.g., /drɪz/-/driz/). It was predicted that the form with the tense vowel would be chosen as the plural since the backformation of a singular from CVz [-tns] would yield a stem which violates the lax vowel constraint.

Set 6 involved three pairs of the form bVz [-tns] (e.g., /bɪz/-/bɛz/). This allows one to compare the ease with which the lax vowel constraint can be violated for different vowels in the same consonant frame. Set 7 contained the real English words. (See Table 11 for a summary of the test types).

Table 11

SAMPLE ITEMS FROM EACH SET IN EXPERIMENT 4

	Sample Item	Purpose
1.	pɛl - pɛlz	Singular vs. plural with overt marker: sonorant stems
2.	sti - stiz	Singular vs. plural with overt marker: tense vowel stems
3.	pɛls - pɛlz	Separate morphemes: proper name ("Pelse") (sg.) vs. plural (pell-pells); sonorant stems
4.	skes - skez	Same as 3 but with tense vowel stems
5.	drɪz - driz	Same as 3 but with tense vs. lax stems
6.	bɪz - bɛz	Forced choice of plural from two non-plural lax stems
7.	ant - ants	Real English words

All subjects were given the items in the same random order; the plural was read first for half of the pictures and the singular form was read for the other half (the presentation order within pairs was also randomized across pairs).

Procedure: Subjects were tested in the same environment as in Experiment 1. Each of the 8 subjects was instructed to choose one of each pair of words as the best name for what he saw in the picture. This experiment took approximately five minutes.

Results: The results of Experiment 4 were divided into three sections. The first section, involving sets 1 and 2, simply tested whether subjects would make use of the regular plural formation rules in choosing the **plural** or **singular** form of a word to describe a picture of one or more figures. In a Chi Square analysis, it was found that the subjects did, in fact, use the plural marking cues in their choice between the two words ($X^2 = 16.68$, $p < .05$).

In Sets 3 and 4 subjects were tested for use of a plural voicing agreement SPC in their choices (e.g., /pɛls/-/pɛlz/). Since the choices were non-random and in the predicted direction ($X^2 = 8.31$, $p < .05$) we may conclude that subjects were making use of the rule. Since we have evidence that subjects are able to base their judgments on the voicing agreement rule for sonorants and tense vowels, we conclude that this type of task is appropriate for testing rule use.

In the crucial third part of the experiment (Set 5), the subjects were expected to choose between two words as names for a picture on the basis of their knowledge of LVC. In this case, however, the choice behavior was random ($X^2 = 1.61$, $p > .05$), indicating that the subjects did not make use of the information about the preceding vowel.

Discussion: It would appear that the non-use of LVC is task specific. One subject, who had trouble with the task, was prompted with the suggestion that he decide what **one** of the creatures would be called. He concluded that a picture showing two animals must be [bez] and not [bɛz] since "one couldn't be called a [bɛ]"; however, he did not use this knowledge on subsequent items.

The first two sections of this experiment demonstrate that the subjects did not simply assume that the nonsense items were irregular plurals, since in cases where the sonorant rule governed the choice (e.g., /<u>lorz</u>/-/lors/ for a plural picture), and in cases where either form would be allowed (e.g., /bli/-/bliz/ for a singular figure) they chose the forms with plural markers as plurals (Sets 1 and 2), and decided what constituted a plural marker on the basis of the preceding consonant (Set 3). Unfortunately, Sets 4 and 5 provided too little data for analysis.

The error rate for Set 5 was 39.3%, much higher than for Sets 1, 2, and 3 (12.5%, 12.5%, and 14.1%, respectively). It would appear that although the picture labelling task does cause subjects to access two aspects of pluralization (-Ø marks singular and -z marks plural; only -z is a plural marker after r, n, or l), it does not tap knowledge of the lax vowel constraint. Subjects rejected /nɑr/ and /nɑrs/ as plurals, but accepted either /bɛz/ or /bez/.

Further analysis of the frequency of error for each vowel was not carried out due to the small amount of data.

2.2.2.5 Experiment 5: Picture Choice (One Word, Two Pictures)

Subjects: The subjects in this experiment were the same as those in Experiment 1.

Materials: The pictures used were like those employed in Experiment 4; one of each pair depicted a single person/animal, the other card showed two. Each item from a word list containing 35 monosyllables was randomly matched with one such pair of pictures. The word list contained six sections, similar to those of Experiment 4. Section 1 contained words ending in sonorants (singulars) and sonorants plus /-z/ (plurals). Set 2 consisted of words ending in vowels and vowels plus /-z/. Section 3 contained words ending in sonorants plus /-s/ (singulars). Section 4 contained words ending in vowel plus /-s/ (singulars). Section 5 was the crucial section for testing LVC, since it consisted of words ending in a lax vowel plus /-z/ (e.g. /bɪz/). It was predicted that these names would be matched with cards with single figures since, if the words were considered to be plural, the singular form (minus /-z/) would break LVC. However, such words could serve as proper names for the individual animal (e.g., "Spizz"). Section 6 contained real English words.

Procedure: The subjects were tested under the same conditions as in Experiment 1. Each subject was instructed to choose the picture to which each name referred: sometimes the singular picture was presented on the right, sometimes on the left; this was varied across pairs but kept constant across subjects. This experiment took about six minutes.

Results: The results are divided into three sections. On each trial, a word from Set 1 or 2 (see Experiment 4) was to be matched with the appropriate picture, presumably on the basis of the regular plural formation rule of adding a /-z/ after vowels and sonorants. The subjects' choices were non-random ($X^2 = 14,07$, $p < .05$) and in the predicted direction. The fact that subjects seldom chose a picture of two figures for a woord with no sibilant ending indicates that they were not thinking of such words as irregular plurals.

In the second section of this experiment, one item was eliminated before the analysis was performed. The word [gɪns], by analogy with the English word *fence*, was expected to obtain the same results as [dərs] and [dɛls]. However, this was not the case, since an epenthetic [t] intruded, allowing subjects to perceive the word as /gɪnts/ (the plural of /gɪnt/). Once this item was removed it was found that the number of items in the section was too small for data analysis; this section of the experiment was run again as Experiment 6 (below).

In the third section of the analysis, subjects chose between singular and plural pictures for items such as /θʊz/ (predicted to be viewed as singular; otherwise one would backform the singular */θʊ/. The choices in this case were found to be random ($X^2 = 1.66$, $p > .05$).

Discussion: As in Experiment 4, the lax vowel constraint was not accessed in distinguishing between singular and plural pictures, although as is shown in Experiment 6 below, subjects were able to use another rule, the voicing assimilation rule for sonorants, to distinguish them from plurals.

2.2.2.6 Experiment 6: Repetition of Second Section of Experiment 5

Subjects: The four subjects were all native speakers of English with restricted exposure to other languages and no speech or hearing disorders. They were all known to the experimenter and were willing to do the task voluntarily. The two male subjects were 21 and 52 years old and the female subjects were 26 and 46 years old.

Materials: The pictures used in this experiment were the same as in Experiment 5. The word list contained the three words from Set 3 in Experiment 5 as well as two additional words ending in /ls/, /rs/ and several distractors.

Procedure: The subjects were tested individually in a quiet room and their responses were recorded on paper by the experimenter.

The experimenter read the instructions to each subject and then read the word list. This task took approximately two minutes.

Results: Only one error was made (Subject 3, *tors*): choices were non-random and in the predicted direction ($X^2 = 16.97$, $p < .05$).

Discussion: This indicates that, as in Experiment 4, the subjects are able to make a choice between two pictures based on their knowledge of the voicing assimilation of the plural rule for sonorants, although they did not use a LVC in Experiment 5 above.

2.2.2.7 Experiment 7: Two Words, Two Pictures

Subjects: The subjects were the same as in Experiments 1 to 5.

Materials: The pictures were like those used in Experiment 5.

Each of 24 monosyllabic word pairs was matched with a pair of pictures and the subject was asked to assign each of the words to one or the other of the pictures. All of the subjects were read the same list of words in the same order. As in the previous experiments, the word list was a mixture of words from different sets. Set 1 pairs contained one word ending in a sonorant (l, 4, or n) and the same word plus /-z/ (e.g., /dur/-/durz/). Set 2 pairs contained one word ending in a vowel and the same word plus /-z/ (e.g., /spu/-/spuz/). These two types involved the use of the rules of regular plural formation.

Set 3 word pairs contained one word ending in a sonorant plus /-s/ and the same word ending in the sonorant plus /-z/ (e.g., /dɛls/-/dɛlz/). Set 4 word pairs contained one word ending in a vowel plus /-s/ and the same word ending in the vowel plus /-z/ (e.g., /vos/-/voz/). Sets 3 and 4 thus involved the use of the voicing agreement rule.

Set 5 word pairs consisted of two words ending in /-z/, indentical except for the fact that the vowel in one word was lax while the vowel in the other word was tense. This section tested whether subjects would choose the form with the lax vowel as plural, since the singular form without the plural marker /-z/ would violate the LVC (e.g., /drɪz/-/driz/).

Procedure: The subjects were tested under the same conditions as in Experiment 1. Each subject was instructed to assign each of the names read to him by the experimenter to one of the two pictures. The words were presented in the same order with the same pictures for each subject except subject 8. The word pairs were always read in the same order in the list, but the order of presentation was varied within pairs. This alteration, however, differed for the eighth subject. The picture of the single figure was always on the subjects' left. This test lasted approximately four minutes.

Results: The results for this experiment were divided into three sections. The first section tested the subjects' ability to use the plural formation rules to choose between the two names (e.g., /dur/ (sg.) vs. /durz/ (pl.)). The choices in this section were non-random and in the predicted direction ($X^2 = 14.13$, $p < .05$). Subjects were thus able to access the rule in making their decisions. The second section tests the subjects' ability to make the choice based on the voicing assimilation rule (e.g., /dɒs/ (sg.) vs. /dɒz/ (pl.)). Again, the choices in this section are non-random, and in the predicted direction ($X^2 = 12.86$, $p < .05$).

The third section tests subjects' ability to make the choice on the basis of the LVC (e.g., /tɛs/ (sg.) vs. (pl.) /tez/). The choices were random ($X^2 = 6.26$, $p > .05$).

Discussion: The first two sections of this experiment show that the subjects did not view nonsense words as irregular plurals, and that they were able to make use of two phonological rules in their decisions. Section 3 seems to indicate that the LVC is not a deciding factor. It was noted, however, that 5 of the 11 errors in Section 3 were due to the single pair /smæz/-/smɒz/; this would account for the negative results. It was therefore decided that a more sensitive experiment should be designed (see below).

2.2.2.8 Experiment 8: Repetition of Experiment 7; Additional Items

Subjects: The four subjects tested in this experiment were the same as in Experiment 6.

Materials: The pictures used in this experiment were those used in Experiment 7. Since the word list was longer, some of the pictures were used more than once.

The word list from Experiment 7 was used along with several new items for each section; a total of 18 different Set 5 pairs was employed.

Procedure: The subjects were tested under the same conditions as in Experiment 6. Each subject was read the instructions and then presented with the word list. This test lasted approximately fifteen minutes.

Results: As in the previous pluralization tasks, the data for Sets 1 through 4 were non-random and in the predicted direction (Sets 1 and 2 combined: $X^2 = 21.12$, $p < .05$, Sets 3 and 4 combined: $X^2 = 24.48$, $p < .05$). However, the Set 5 data are also non-random and in the predicted direction ($X^2 = 19.86$, $p < .05$).

Discussion: This experiment showed that the subjects were able to access the relevant SPC in order to distinguish between singulars (proper names) such as /bɛz/ and plurals such as /bez/. Here the error rate is only 12.5% (9 out of 72 responses) items, compared with 39.3% in Experiment 4 and 39.6% in Experiment 5. This suggests that the forced double matching technique does result in access of the constraint in distinguishing between singulars and plurals.

3. General Discussion

As shown in the experiments of this study, the lax vowel constraint is available to subjects in some tasks, but they do not access it fully. It appears as an influence in the error rates in memory and imitation (both harder in words that break LVC), in a forced-choice task (two words/two pictures), and in the syllable-division task in that the only changes in V/C words were to lax vowels, but never with 100% effect. The syllable structure strategies in the language game overpowered the LVC and subjects just did not use it in the first two of the pluralization experiments. A speaker of English can operate without knowledge of this rule because no environments for its application occur. For example, LVC does not enter into any morphological alternations in which misapplication of the rule would result in errors. Instead, speakers simply learn the English lexicon without final lax vowels and if the constraint is internalized by some individuals, this is perhaps best described as incidental learning.

The results of the syllable-division experiment suggest that the LVC is not operative at the syllable level, and thus it is easier to break at the word level; the subjects allowed a syllable to end in a lax vowel. This is significant because dictionary editors, in their syllable divisions, implicitly claim that it is operative at the syllable level. This experiment has both resolved the syllable-level question, and explained why the constraint is weaker at the word level (analogy to open lax-vowel-final syllables word-internally).

In spite of suggestions from Moskowitz (1973) and Read (1971) that tense/lax relationships between vowels are available to speakers, this knowledge has no discernable effect on normalization. None of the data showed a significant tendency to normalize lax vowels by tensing them. With a much larger sample some patterns might emerge, but it would not likely be a tensing pattern (e.g., other strategies such as centralizing and inserting an offglide were as common as tensing strategies).

Borrowing is probably the only criterion for rule productivity that approaches 100% application. Hsieh (1970) also found a rule (a Taiwanese tone sandhi rule) to have low productivity in nonsense words yet the rule is productive in borrowings (Smyth 1983, personal communication).

Our data show that the LVC may not be very productive for an individual, even though the speech community might always observe it. One might claim that DeSaussure's (1955) *langue/parole* distinction better captures this than Chomsky's (1965) *competence/performance*: we assume that an individual speaker does not need to know the rule (he does not have it in his *parole*) although the speech community as a whole will always apply it in borrowings (*langue*). Chomsky's *competence/performance* distinction would suggest that all speakers do have the distinction internalized (competence) but just fail to use it on these tasks (performance failure). Probably a solution would lie in sociolinguistic investigations of how the speech community gradually "vetoes" foreign pronunciations so as to normalize the words.

In summary, experimental investigations of rule productivity provide interesting insights into the psychological representation of linguistic rules including task- and subject- dependent factors which account for variable productivity.

FOOTNOTES

[1]Stress is indicated throughout this paper by an apostrophe immediately preceding the stressed syllable.

[2]For detailed information regarding specific tasks, see Westby (1983) *Variable Productivity: Evidence from the English Lax Vowel Constraint.*

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