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Strategies and Constraints :

The Role of Preference Theory in Language Processing

by

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Abstract

The role of the Preference Laws for Syllable Structure (Vennemann 1988) in language processing is investigated in this thesis through two psycholinguistic experiments. We employed a calculus-based operationalization of the Preference Laws in order to compare a wide range of non-word monosyllabic configurations. In our studies the response time latencies generated in response to these stimuli were correlated with the relative ease of production of a given configuration. Shorter response time latencies are indicative of configurations which are easier to produce. And, as we have shown, ease of production corresponds to the more preferred nature of configurations as defined by our operationalization of the Preference Laws.

The stimuli in our first experiment conform to the phonotactic constraints of English. While the stimuli in our second experiment move beyond the phonotactic constraints. The positive results from both experiments serve to validate our methodology, choice of stimuli and use of RT latencies as a measure of overall processing. More importantly, however, our findings support the language specific and universal claims of the Preference Laws. Our experiments represent the first psycholinguistic investigations into the universal nature of Preference and its role in language processing.

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Chapter 1

The Syllable: A Phonological Perspective

> "It is, of course, an old insight in both phonetics and phonology that segments are organized into syllables. In large parts of the phonological tradition, this insight was never lost. But in SPE, there was no syllable. Since generative phonology has traditionally been rule-oriented rather than structure-oriented, the arguments for the reintroduction of the syllable paradigm are based on the idea that rules must refer to syllabic structures."
> (Newmeyer 1988: 201)

1.1 Syllable Structure

One of the most influential theoretical developments affecting the study of phonology in this century was the publication of The Sound Patterns of English (SPE) (Chomsky and Halle 1968). The SPE framework emphasized the morpheme (i.e. as defined by the morpheme boundaries + and #) as the proper domain for the characterization of phonological processes. In no portion of the theory were either the syllable (σ) or the syllable boundary ($) considered.

In a break with SPE tradition, Hooper (1972, 1976) began to consider the advantages to be gained from the adoption of the syllable as the proper domain for the formulation of rule-governed phonological processes. For example, the

SPE characterization of vowel lengthening in Icelandic would require rules (1) and (2) (based on Vennemann 1972:3-8):

(1)

$$V_{[+stress]} \text{ -> } [+long] \text{ / } \_CV$$

(2)

$$V_{[+stress]} \text{ -> } [+long] \text{ / } \_\{p,t,k,s\}\{r,j,v\}V$$

Though descriptively accurate, the SPE rules fail to recognize lengthening as a uniform process applying in the situation created by the environments specified in (1) and (2)- namely in an open syllable[1].

Therefore, with reference to syllable boundaries, these rules can be more accurately restated as in rule (3):

(3)

$$V_{[+stress]} \text{ -> } [+long] \text{ / } \_\$$$

The use of the syllable boundary in rule (3) is a preferable means of specifying the conditioning factors for the lengthening process as it identifies the conditioning environment as an open syllable. Given that many phonological processes can be more precisely stated in terms of syllables than morphemes, Hooper (re)motivated the need to recognize the syllable in phonology.

Hooper characterized the syllable as a linear sequence of consonantal and vocalic elements without sub-syllabic groupings. In order to delineate the language-specific characteristics and constraints on the syllable, Hooper (1972) developed the Universal Syllable Template in Figure 1.

---

1 In Vennemann (1972) a syllabification rule would precede rule (3). The syllabification rule specifies which segments can function as syllable onsets. The rule therefore, treats the detail given in rule (2).

$$C_0^n V C_0^n$$

Figure 1.1 - The Universal Syllable Template

This linear representation identifies the possible iterations of consonantal elements (C) ranging from 0 (the subscript) to n (the superscript), pre- and post-vocalically. The symbol V refers to the segment of maximal sonority or resonance (i.e. either a vocalic element or a syllabic consonant). Sonority refers to "a quality attributed to a sound on the basis of its seeming fullness or largeness, and when attributed to speech sounds, sonority is correlated with the degree of voicing. There is very little discernable difference between the sonority of any two speech sounds produced without voice. For this reason sonority may be equated with acoustic energy" (Heffner 1975:74).

It should be noted that sonority serves to distinguish not only between consonantal and vocalic segments (i.e. C's and V's), but also between different consonants. Hence based on Sievers (1901),

(4)

a- voiced segments are more sonorant than their voiceless counterparts
b- continuants are more sonorant than non-continuants
c- nasals and liquids are more sonorant than voiced fricatives
d- mid and low vowels are more sonorant than high vowels
e- low vowels are more sonorant than mid vowels

The Universal Syllable Template represents the universal range of possible configurations within a syllable. In any given language a subset of the universal range is selected as that language's specific syllable template. For example, if a language's template were $C_0^1 V$, a string like badake could be a word in that language because ba, da, and ke are all syllables which conform to the language's template. However, the occurrence of a string such as baddake would be prohibited because either of the possible syllabifications, <u>baddake</u> or <u>baddake</u>, would constitute a violation of the language's C_0^1V syllable template.

In addition to identifying the universal range of syllabic configurations, Hooper identified the CV syllable as the Optimal Syllable. The optimal or canonical status of this structure refers to the maximally natural or unmarked nature of the CV syllable based on the fact that this is the only syllable type which occurs in all of the world's languages.

Reference to syllables led to the identification of phonological rules, relations and regularities which are specifically syllable dependent. For example, tone as in Chinese, pitch-accent contours as in Japanese, nasalization as in French, and vowel harmony as in Turkish (Clements & Keyser 1983; Hayes 1982, 1984; Hogg & McCully 1987). As a result, phonologists began to investigate the internal organization of the syllable in order to clarify the nature of syllable dependent processes. The investigation of different syllabic processes has led to a number of distinct proposals concerning the internal organization of syllables (e.g. Clements & Keyser 1983; Kahn 1976; Kaye, Lowenstamm & Vergnaud 1985 and Vennemann 1972, 1988). In the sections below the key features of some of the more influential of these proposals will be outlined.

All of the theories which we will consider share the view that a syllable can be organized into, at least, three significant constituents, the head, nucleus, and coda, where:

(5)

a) The nucleus (N) is the segment of maximal sonority (i.e. resonance) which corresponds to the V in the syllable template (Figure 1.1). It is the only obligatory element within a syllable.

b) The head (H) consists of all the consonantal segments between the nucleus and the preceding syllable boundary.

c) The coda (C) consists of all of consonantal segments between the nucleus and the following syllable boundary.

The simplest model which we will consider has been termed the Flat model (Kahn 1976; see Vennemann 1988 for discussion). This model, represented in Figure 1.2, recognizes the syllable (σ) as the superordinate organizational unit directly dominating the head, nucleus and coda units[1] .

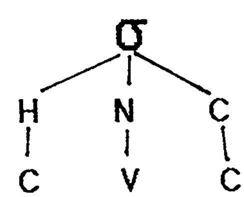


Figure 2 - The Flat Model of the Syllable

It is worth noting that the trinary configuration of the Flat Model implies that all terminal constituents are independent and equal by virtue of their sisterhood.

In contrast to the Flat model, the Right-Branching hierarchical model (Selkirk 1980), depicted in Figure 1.3, introduces an intermediary constituent, the rhyme (R) which results from the union of the nucleus and the coda (Clements & Keyser 1983; Kahn 1976; Kiparsky 1980; Selkirk 1980).

[1] We will be using the terms "terminal constituent" and "terminal unit" to refer to the subsyllabic head, nucleus and coda units. Individual phonemes will be referred to as either terminal elements or segments. Hence, terminal constituents bear a superordinate relationship to terminal elements.

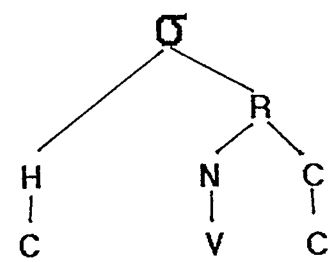


Figure 1.3 - The Right-Branching Hierarchical Model

It should be noted that the introduction of an intermediate constituent in the hierarchy alters the relations between the terminal units. More specifically, in this model, the nucleus and coda are sisters dominated by the rhyme, while the head and the rhyme are sisters dominated by the syllable. Hence, the head and coda no longer exhibit the equality of status they did in the Flat model.

The postulation of a rhyme has resulted in the successful characterization of phonological phenomena which could not be accounted for under the Flat or Left-Branching model. For example, the Right-Branching model has been extended and refined within the Metrical Phonology framework which focuses on stress placement within a binarily constrained hierarchical model (Hogg & McCully 1987; Kiparsky 1980; Lieberman & Prince 1977). The polar values of prominence (i.e. weak and strong) represent the ideal extremes of sonority. Stress is assigned to a syllable based on the cumulative effects of the more or less prominent nature of its subsyllabic elements.

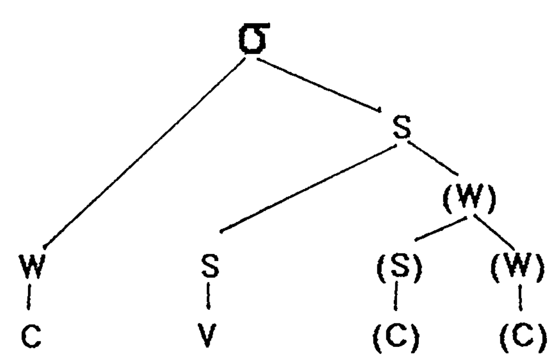


Figure 1.4 - Metrical Prominence Assignment

If we consider the subsyllabic units of the Right-Branching model in terms of the binary constraints of the Metrical approach, as represented in Figure 1.5, we find that the head is weak with respect to the rhyme and the coda is weak with respect to the nucleus (based on Kiparsky 1980). This is in keeping with Sievers' (1901) observation that sonority within a syllable tends to increase from the onset towards the nucleus and decrease from the nucleus towards the final margin.

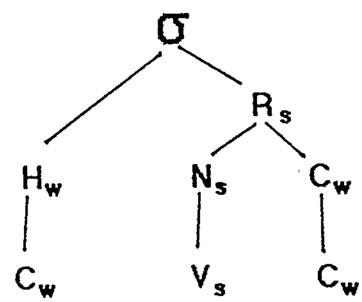


Figure 1.5 - The Prominence of Subsyllabic Units

If we consider the prominence profile of Figure 1.5 in terms of the Optimal Syllable, we can infer that a weak segment (i.e. an element low in sonority, ideally a C) in initial position is universally favoured over a consonantal segment in any other position and that a consonantal segment is favoured over a sonorant element syllable initially. That is to say, the Optimal Syllable is a CV syllable comprised of maximally dissimilar elements, where the head is maximally consonantal, the nucleus is maximally sonorant.

However, as we saw in (4) sonority may be considered a scalar feature. Therefore, we should be able to compare syllables like /ta/,/ri/ and /tat/ in terms of how well they approximate the canonical form. Unfortunately, gradient rankings cannot be accommodated in theories which impose binary constraints both on features (i.e. sonority) and structures.

In order to facilitate gradient comparisons, we will now turn our attention to the theoretical foundations of Preference Theory (Vennemann 1988). Preference Theory is based upon the graded classification of segments resulting from the interactive effects of the segmental and positional strengths associated with the (sub)syllabic configurations. As we will see, this framework is based upon a universal set of Preference Laws which govern and define syllabic structures and processes.

1.2 Syllable Preference

As suggested in Section 1.1, the need for a gradient perspective in syllabic phonology has been motivated by the fact that binary distinctions (e.g. distinctive features) cannot adequately account for the gradient nature of some phonological oppositions and rules. The Preference Laws for Syllable Structure (Vennemann 1988) were developed in order to characterize the interactive effects of segmental and positional strengths which have been shown to contribute to the gradient nature of phonological change (see also Murray 1988).

Within this framework the scalar ranking of segments is based upon the gradient nature of sonority. The scalar comparisons of segments suggested in (4) led to the development of a sonority continuum ranging from low unrounded back vowels (i.e. maximally sonorant) to voiceless stop consonants (i.e. maximally consonantal). Given that many historical phonological changes typically can be thought of as consonantal strengthenings or weakenings, Vennemann proposed to rank segments in terms of Consonantal Strength. Consonantal Strength is a cover-term which corresponds inversely to the degree of sonority exhibited by a segment. Accordingly, the Consonantal Strength Scale, Figure 1.6, assigns the greatest Consonantal Strength to voiceless stops and the weakest Consonantal Strength to low unrounded back vowels[1].

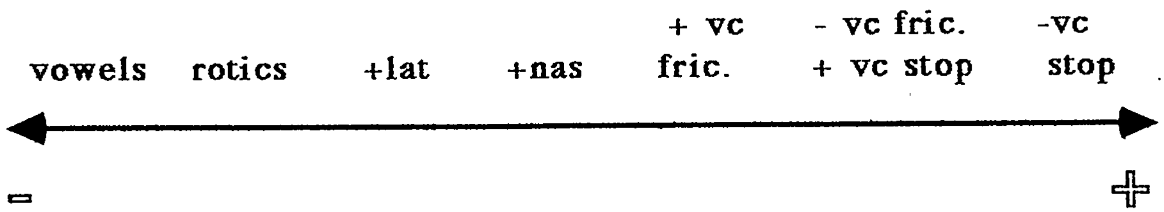


Figure 1.6 - The Consonantal Strength Scale

If we return to our question concerning the comparison of the /ta/, /ri/ and /tat/ type syllables, we can conclude, based on the Consonantal Strength Scale, that /ta/ more closely approximates the Optimal Syllable than /ri/ because /t/ and /a/ are the ideal extremes of Consonantal Strength.

However, in order to compare /ta/ and /tat/ we must consider the effects of positional strength which result from the degree of Consonantal Strength preferred in each subsyllabic position of the Optimal Syllable. As we saw, a head is ideally formed from a single consonantly strong segment and a nucleus is ideally formed from a consonantly weak segment. Consequently, we can conclude that the head is the strongest position in the syllable, the nucleus the weakest, and the coda (if it exists) should range between the two. The relative strength of a position facilitates the occurrence of segments of the ideal strength

[1] The term "strength", henceforth will be used to refer to Consonantal Strength, unless otherwise specified.

and the processes which convert less appropriate segments. Therefore, returning to our question concerning the optimal nature of /ta/ vs. /tat/, we can conclude that /ta/ is more ideal than /tat/ and that the final /t/ in /tat/ should be more susceptible to weakening processes which will convert the maximally strong /t/ to a weaker segment (or ideally to a null element) which is a better approximation of the Optimal Syllable. As we will see in the following sections, the interaction of segmental and positional strength can be reduced to a single value - Slope. The Slope Value (SV) assigned to a subsyllabic unit can be thought of as a coefficient referring to the interactive effects of configuration and composition of the subsyllabic unit. We will now consider Vennemann's approach to the determination of preference values for syllabic structures.

1.2.1 The Preference Laws

The Preference Laws characterize the language specific constraints which govern the interactions of positional and segmental strengths relative to a given parameter. That is to say, given the universal principles and the language specific parameters which apply to syllabic structures it is possible to compare these structures in a gradient fashion. The graded comparison will indicate which structure is more or less preferred. Less ideal structures are said to be more susceptible to change and every change is said to be a local improvement[1].

In Vennemann's framework, preferred configurations are a function of its three terminal units- the head, nucleus and coda. The factors which determine

[1] The term "local" refers to the domain of a particular Preference Law or sub-part of a Preference Law. However, Vennemann does not provide a means of weighing the relative merits of a variety of local improvements against one another. As a result, a variety of possible "local" alterations could improve the evaluation of a less preferred syllable structure to varying degrees.

the preference of each of these units is formalized in the following Preference Laws.

1.2.1.1 The Head Law

In the Preference Laws for Syllable Structure the ideal phonological nature of the head (i.e. the consonants preceding the nucleus) is captured by the Head Law (Vennemann 1988: 14) in (6).

(6) Head Law:

A syllable head is the more preferred :

(a) the closer the number of speech sounds in the head is to one;

(b) the greater the Consonantal Strength value of its onset, and

(c) the more sharply the Consonantal Strength drops from the onset towards the Consonantal Strength of the following syllable nucleus.

The Head Law implies that, based on the Consonantal Strength Scale (Figure 1.6), strong monoconsonantal heads are preferred to weaker monoconsonantal heads and that monoconsonantal heads are preferred to diconsonantal or triconsonantal clusters (i.e. **({/t/, /p/, /k/} >> {/b/, /d/, g/} .../r/) >> CC >> CCC**, where the symbol **>>** is read as "is more preferred than"). This means that the preferred head construction will result in a sharp drop from the onset of the head to the following nucleus.

1.2.1.2 The Nucleus Law

As mentioned in (5a), the nucleus is the backbone of a syllable and its occurrence within a syllable is obligatory. The Nucleus Law (Vennemann 1988: 27) in (7) characterizes the preferred nature of a syllable nucleus.

(7) Nucleus Law:

A nucleus is the more preferred:
(a) the steadier its speech sound, and
(b) the less the Consonantal Strength of its speech sound.

Thus, a single low back unrounded vowel is more preferred than any other single vowel and single vowels are preferred over diphthongs or triphthongs (i.e. **($V_{[+bk, -hi, -rd]}$ >> $V_{[-bk, +hi, -rd]}$) >> VV >> VVV**).

1.2.1.3 The Coda Law

The Coda Law (Vennemann 1988: 21) in (8) formalizes the specific limitations pertaining to the consonant following the nucleus.

(8) Coda Law:

A syllable coda is the more preferred:
(a) the smaller the number of speech sounds in the coda;
(b) the less the Consonantal Strength of its offset,
(c) the more sharply the Consonantal Strength drops from the offset towards the Consonantal Strength of the preceding syllable nucleus.

It is important to note that a conflict exists concerning the local characteristics defining the ideal coda. Subsections (b) and (c) are in direct opposition despite the fact that they refer to the same domain. Condition (b) implies that the final element of a coda should be consonantly weak (i.e. **/r/ >> /l/ ... >> {/t/, /p/, /k/}**). In contrast, subsection (c) implies that the final element of a coda should be consonantly strong (i.e. **{/t/, /p/, /k/} >> {/b/, /d/, g/} ... >> /r/**). However, both agree that a simple coda is preferred (i.e. **0 >> C >> CC >> CCC**).

The static state of the Preference Laws, as expressed by the Synchronic Maxim, implies that if a language contains a less preferred structure, it should by definition, also contain the more preferred correlate(s). The Synchronic Maxim can be viewed as a means of characterizing the current segmental and configurational inventory of languages and the basis for cross-linguistic comparisons (cf. Li 1989).

Given that the distributional, physical and functional characteristics of segmental and positional strength "have their basis in the human productive and perceptive phonetic endowment" (Vennemann 1988:4), there are two key points, which should be noted, concerning the relationship between the synchronic and diachronic propensities for language change. First, within any given language (at any given point in time) there will exist a set of less preferred structures which, from a synchronic perspective, will be more difficult for native-speakers to learn and use.

Second, from a diachronic perspective, the same set of structures will be more susceptible to change. Therefore, a causal relationship can be established between synchronic difficulty and the propensity for diachronic change based on the fact that Preference Theory is rooted in our productive and perceptive phonetic endowment (Vennemann 1988:4). Consequently, the study of synchronic and diachronic change provides us with a window into the nature of the principles and parameters of the Preference Theory and the intricacies of language in general.

Murray, having conducted the much of the linguistic investigations concerning the gradient nature of language change, focused on the diachronic perspective. Based on numerous phonological reconstructions, Murray (1987b: 115) observed that "sound change typically does not affect all the members of a particular class, rather only a subsection of the class, with [or without] subsequent generalization to the other members". His research also demonstrates that the gradient nature of the phonological processes responsible for historical changes can be accounted for through the application of universal principles and language specific parameters of the Preference Laws for Syllable Structure.

In a preliminary investigation of the synchronic role of the Preference Laws in language processing, Li (1989) equated the more or less preferred nature of syllabic structures with response time latencies and error rates. Li's results indicated that there are measurable differences between cluster types. More importantly, it was shown that these differences correspond with the more or less preferred nature of the syllabic configurations investigated. As would be expected, Li's results indicate that the more preferred structures correlate with the shorter response time latencies and lower error rates. Thus, Li's study demonstrates that the Preference Laws for Syllable Structure are a viable means of investigating the gradient nature of the principles and parameters of natural language processing relevant to synchronic syllabic structures.

However, as we will see in Chapter 2, Li's findings and conclusions were constrained by the descriptive nature of the investigation and the high rate of intrasubject variability. In contrast, our study overcomes the primary failings of Li's study through the use of a calculus based evaluation metric (Section 2.3) and population homogeneity. Therefore, despite the difficulties Li encountered, this thesis confidently investigates the role of the Preference Laws governing Terminal Constituents in terms of the key theoretical question :

Are the principles and parameters employed in the Preference Laws for Syllable Structure also relevant to language processing?

The Head, Nucleus, and Coda Laws discussed above, govern the characterization of terminal constituent preferences[1]. Vennemann (1988: 2) has claimed that these laws are relevant to the understanding of language from a diachronic and a synchronic perspective. The Diachronic Maxim in (9), specifies the dynamic propensity for and the preferred direction of change which may affect a language over time.

(9) Diachronic Maxim:

> Linguistic change on a given parameter does not affect a language structure as long as there exists structures in a language system that are less preferred in terms of the relevant preference law .

Hence, the Diachronic Maxim provides us with a means of comparing different developmental stages of a language (c.f. 1984, 1987b; Murray & Vennemann 1983). In a language, it should be the case that less preferred syllabic structures will be subject to change before the more preferred counterparts are affected.

The second maxim, the Synchronic Maxim (Vennemann 1988: 3) in (10), defines the constraints on the segmental and structural configurations which exist in a language at a given point in time.

(10) Synchronic Maxim:

> A language system will in general not contain a structure on a given parameter without containing those structures constructible with the means of the system that are more preferred in terms of the relevant preference law.

---

[1] In addition to the Terminal Constituent Laws, the Rhyme, Body and Shell Laws characterize the preferred structure of intrasyllabic intermediary constituents, while The Contact Law governs the assignment of intersyllabic preference relations.

The static state of the Preference Laws, as expressed by the Synchronic Maxim, implies that if a language contains a less preferred structure, it should by definition, also contain the more preferred correlate(s). The Synchronic Maxim can be viewed as a means of characterizing the current segmental and configurational inventory of languages and the basis for cross-linguistic comparisons (cf. Li 1989).

Given that the distributional, physical and functional characteristics of segmental and positional strength "have their basis in the human productive and perceptive phonetic endowment" (Vennemann 1988:4), there are two key points, which should be noted, concerning the relationship between the synchronic and diachronic propensities for language change. First, within any given language (at any given point in time) there will exist a set of less preferred structures which, from a synchronic perspective, will be more difficult for native-speakers to learn and use.

Second, from a diachronic perspective, the same set of structures will be more susceptible to change. Therefore, a causal relationship can be established between synchronic difficulty and the propensity for diachronic change based on the fact that Preference Theory is rooted in our productive and perceptive phonetic endowment (Vennemann 1988:4). Consequently, the study of synchronic and diachronic change provides us with a window into the nature of the principles and parameters of the Preference Theory and the intricacies of language in general.

Murray, having conducted the much of the linguistic investigations concerning the gradient nature of language change, focused on the diachronic perspective. Based on numerous phonological reconstructions, Murray (1987b: 115) observed that "sound change typically does not affect all the members of a particular class, rather only a subsection of the class, with [or without] subsequent generalization to the other members". His research also demonstrates that the gradient nature of the phonological processes responsible for historical changes can be accounted for through the application of universal principles and language specific parameters of the Preference Laws for Syllable Structure.

In a preliminary investigation of the synchronic role of the Preference Laws in language processing, Li (1989) equated the more or less preferred nature of syllabic structures with response time latencies and error rates. Li's results indicated that there are measurable differences between cluster types. More importantly, it was shown that these differences correspond with the more or less preferred nature of the syllabic configurations investigated. As would be expected, Li's results indicate that the more preferred structures correlate with the shorter response time latencies and lower error rates. Thus, Li's study demonstrates that the Preference Laws for Syllable Structure are a viable means of investigating the gradient nature of the principles and parameters of natural language processing relevant to synchronic syllabic structures.

However, as we will see in Chapter 2, Li's findings and conclusions were constrained by the descriptive nature of the investigation and the high rate of intrasubject variability. In contrast, our study overcomes the primary failings of Li's study through the use of a calculus based evaluation metric (Section 2.3) and population homogeneity. Therefore, despite the difficulties Li encountered, this thesis confidently investigates the role of the Preference Laws governing Terminal Constituents in terms of the key theoretical question :

Are the principles and parameters employed in the Preference Laws for Syllable Structure also relevant to language processing?

Chapter 2

The Syllable: A Psycholinguistic Perspective

> "Discovering order in apparent randomness, universality in language-specific details, explanations for what seemed just facts to live with, appears to me to be genuine progress. Even so, our knowledge is to date merely disparate and fragmented. Yet, I am confident that as we follow this course of investigation, we will gain ever more, and more, coherent insights."
>
> T. Vennemann (1988)

As discussed in Section 1.2, this thesis presents a calculus-based psycholinguistic investigation of the role of the Preference Laws governing Terminal Constituents in language processing. The phonological advancements which led to the development of the gradient view of phonology formalized in the Preference Laws for Syllable Structure were discussed in Chapter 1. In this chapter, we will review briefly a number of psycholinguistic studies which have found a relationship between aspects of syllable structure and language processing. It is interesting to note that the linguistic developments germane to the re-introduction of the syllable in phonology were paralleled and supported by the experimental findings of the psycholinguistic studies to be discussed in Section 2.1.

A review of a number of psycholinguistic studies will be followed by an in-depth treatment of Li (1989). To date, Li's study is the only psycholinguistic investigation into the synchronic application of the Preference Laws. Based on a re-analysis of Li (1989) we will show that the inconclusive nature of her findings can be primarily attributed to the constraints imposed by the nature of her design, the descriptiveness of her evaluation method, and by the high rate of intrasubject variability in her data. That is to say, we will argue that, despite the difficulties Li encountered, it is possible to identify the effects of Preference Theory in language processing through the use of response time (RT) latencies if a less descriptive evaluation metric is used.

In the final sections of this chapter, we will present our calculus based evaluation metric which we claim overcomes the difficulties associated with the descriptive nature of the Preference Laws.

2.1 Psycholinguistic Investigations of Syllabic Structures

Early psycholinguistic investigations clearly identified the syllable as a parsing unit employed during auditory processing (Treiman & Danis 1988) and visual processing (Barry 1984; Millis 1986). These "psychological reality" studies served to support Hooper's early work on the syllable as a theoretical primitive. The interdisciplinary resurgence of interest in the syllable prompted subsequent psycholinguistic investigations into the role of subsyllabic units in language processing.

In a series of seven ground-breaking experiments, Treiman (1983) set out to selectively investigate the internal organization of syllables based on Clements & Keyser's (1983) claim that the rhyme is a more natural unit than the body (i.e. the union of the head and the nucleus). In Treiman's study adults were required to learn to use word-game rules which would manipulate phonemes or strings contained within the test items. Treiman hypothesized that if subjects tended to use rules which manipulate a given subsyllabic unit more frequently and accurately, then the ease of manipulation of subsyllabic structures via these rules could be taken as an indication of the unit's "naturalness" or psycholinguistic reality.

Based on the choice of rules which subjects employed, Treiman (1983: 49) observed that adults learning word games tended to (a) learn rules which apply to subsyllabic units (i.e. head, coda or rhyme) more readily than rules which manipulate single phonemes, and (b) prefer to manipulate strings which correspond to heads and rhymes. As a result, Treiman concluded that her findings could be taken as evidence in support of (a) the existence of subsyllabic units, (b) the preference for the manipulation of subsyllabic units (i.e., as opposed to segmental units), and (c) the postulated naturalness of rhyme structures.

Derwing, Nearey and Dow (1987) questioned the validity of Treiman's conclusions. They found that the tendency for segments to function as a unit could be more effectively explained in terms of the greater or lesser tendency for segments to co-occur. That is to say:

(11)

a) Pre-vocalically, resonants (i.e. sonorants) tend to function as a unit with other pre-vocalic consonants and glides tend to remain with the nucleus more frequently than nasals or liquids do.

b) Post-vocalically, nasals tend to function as a unit with the nucleus more often than liquids; liquids tend to function as a unit with the nucleus more often than glides, and resonants function as a unit with the nucleus more often than in any other position.

The observed gradient nature of these collocation restrictions led Derwing, Nearey and Dow (1987) to develop the notion of "vowel-stickiness" which refers to the tendency for pre- or post-vocalic segments to function as a unit with the nucleus. Vowel-stickiness is an alternative means of explaining the preferential nature of head-rhyme syllabic configurations and processes found by Treiman.

Derwing, Nearey and Dow suggested that the responses elicited during Treiman's word-games reflect a more universal set of gradient collocation restrictions, rather than simply subsyllabic constituencies. That is to say, language processing may, in part, depend upon the gradient nature of phonological processes and features.

As we saw in Chapter 1, Venneman's Preference Theory also takes a gradient approach in its characterization of syllable structures. This Preference Theory forms the basis of Li's study which is detailed below.

2.2 A Psycholinguistic Investigation of Syllable Preference

Li's study, "Syllabic Phonology and ESL Production", investigated the degree to which the Preference Laws for Syllable Structure could explain the pronunciation errors produced by Chinese learners of English as a Second Language (ESL) who exhibited a range of English proficiency. She assumed that this population would be an ideal group because Chinese is a CV language[1] and therefore represents the ideal state of a natural language with respect to syllable structure (recall Hooper's (1976) characterization of the Optimal Syllable).

Li theorized that the range of difficulties encountered by Chinese-speakers during the acquisition of English consonant clusters should reflect the

---

[1] Actually, Chinese allows nasals in syllable-final position, therefore it is more accurately characterized as a CV(N) language.

more or less preferred nature of the syllabic configurations. In terms of the Preference Laws, more preferred clusters should generate shorter RT latencies and greater accuracy rates. Li also hypothesized that an interaction would be found between cluster preference and level of ESL proficiency.

With this in mind, Li designed an oral reading task in which Mandarin-speaking ESL learners were asked to read aloud a series of tachistoscopically presented words. The test items employed were designed to represent the syllable-initial and syllable-final diconsonantal clusters of English. The stimuli were restricted to CCVC or CVCC nonsense syllables. The use of nonsense syllables was required to minimize the extra-phonological influences of semantics, word frequency and word length. In addition, Li strove to limit the effects of orthography (i.e., the phonological transparency of grapheme-to-phoneme correspondences) by using only segments which could be represented by a single phoneme. So, for example, Li was not able to employ the segment /š/ in her study because it would have to be represented by the digraph sh.

Furthermore, Li reasoned that, due to the large number of consonant clusters in English and the fine distinctions between them, the preference relations could be more clearly evaluated if the segments forming English clusters were first grouped into the natural classes of Stop, Fricative, Nasal and Liquid. These groups were represented in her study by the symbols T, S, N and L respectively. Li controlled the difficulties associated with the comparison of voiceless segments by using only voiceless stops and fricatives (c.f. Heffner 1975:74). The clusters which Li employed are depicted in Figures 2.1 & 2.2.

Type	Code	Graphemes
stop-liquid	TL-	pr, tr, kr, pl, kl
fricative-liquid	SL-	fr, sl, fl
fricative-nasal	SN-	sn, sm
fricative-fricative	SS-	sf
fricative-stop	ST-	sk, st, sp

Figure 2.1 -
English Diconsonantal Heads (Li 1989)[1]

Type	Code	Grapheme
stop-stop	-TT	pt, kt
stop-fricative	-TS	ps, ks, ts
frictive-stop	-ST	sk, sp, st
fricative-fricative	-SS	fs
nasal-stop	-NT	nt, mp
nasal-fricative	-NS	ns, mf
liquid-stop	-LT	lt, lp, lk
liquid-fricative	-LS	ls, lf
liquid-nasal	-LN	lm

Figure 2.2 -
English Diconsonantal Codas (Li 1989)

[1] It should be noted that sf- is not a valid orthographic representation in English. In fact it is a rare phonological combination as well. These factors may have influenced Li's findings.

Based on the Preference Laws and the constrained inventory of English consonant clusters in Figures 2.1 & 2.2, the prediction matrices depicted in Figures 2.3 & 2.4 were developed. In the following sections, Li's findings based on the predictions for syllable-initial and syllable-final clusters will be analyzed for two purposes: First, we wish to develop a clearer understanding of the observed effects of syllabic configurations on the ease of production. Second, we need to identify the weaknesses within Li's study in order to move beyond their limiting effects.

2.2.1 Head Cluster Analyses

The preference predictions presented in Figure 2.3 for disegmental syllable-initial clusters were developed based on subsections (b) and (c) of the Head Law in Section 1.2.1.1 which state that a head is more preferred, the greater the Consonantal Strength value of its onset and the more sharply the Consonantal Strength drops from the onset towards the following nucleus.

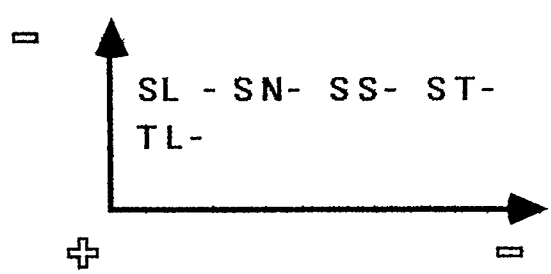


Figure 2.3 - Predicted Preferences for Head Clusters (Li 1989)

The preference relations depicted in Figure 2.3 are summarized in (12) where syllable-initial stop-liquid (TL) clusters are predicted to be more preferred than fricative-liquid (SL) clusters, which should be more preferred than fricative-nasal (SN) clusters, which should, in turn, be more preferred than fricative-fricative (SS) clusters.

(12) Preference Predictions for Syllable-Initial Clusters :

TL- >> SL- >> SN- >> SS- >> ST-

In the analysis of her data, Li found that the RT latency data was less reliable than the accuracy data. Li's subjects were, in general, unpracticed ESL readers with reading strategies based on a letter-by-letter approach. Consequently, the RT data which is calculated from the beginning of a response failed to reveal the processing of the whole string because the obtained RT latencies often reflected individual variations in response methods (i.e. false starts or response internal hesitations).

Li's accuracy results for syllable initial clusters are given in (13). In general, Li found that syllable-initial clusters adhered to the predicted preferences. However, in her accuracy analysis, she found that consonant clusters which began with s- behaved in an exceptional manner. For example, s- followed by a stop, which should represent the least preferred head type, exhibited the highest accuracy rate. Li attributed the exceptional status of the syllable-initial s- to its "extrasyllabicity". Unfortunately, the notion of extrasyllabicity is not contained within the Preference Theory.

(13) Accuracy Rates for Syllable-Initial Clusters

ST- >> TL- SL- >> SN- >> SS-

As can be seen in (13), Li's accuracy data can be taken as support for the Head Law which indicates that a sharp drop from a consonantly strong onset towards the following nucleus is preferred. We find these results encouraging despite the fact that this study was limited by the narrow range of syllable structures considered and that it could not rely on the more sensitive measure of response time latencies in the analysis.

2.2.2 Coda Cluster Analyses

Li's predictions presented in Figure 2.4 for disegmental syllable-final clusters were developed based on subsection (c) of the Coda Law in Section 1.2.1.3 which states that a coda is more preferred the more sharply the Consonantal Strength drops from the offset towards the preceding nucleus. However, as a result of the descriptive nature of her method, Li was unable to deal with subsection (b) of the Coda Law which states that a coda is more preferred the less the Consonantal Strength of its offset. Due to this contradiction, Li could only compare the syllable final clusters in Figure 2.4 vertically and horizontally, but not diagonally.

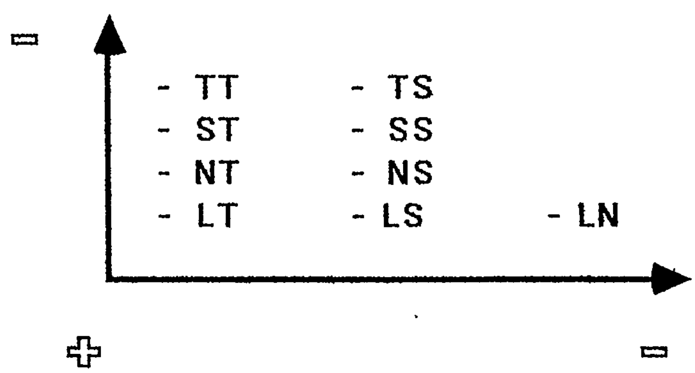


Figure 2.4 - Predicted Preferences for Coda Clusters (Li 1989)

Li's results were investigated in terms of the horizontal and vertical comparisons of cluster types in (14 a-f). The vertical comparisons in (14a) and

(14b) focus on the effect of different coda-initial segments, while the horizontal comparisons in (14c to e) focus on the effect of different coda-final segments.

(14) Li's Coda Predictions

a) -LT >> -NT >> -ST >> -TT

b) -LS >> -NS >> -SS >> -TS

c) -LT >> -LS >> -LN

d) -NT >> -NS

e) -ST >> -SS

f) -TT >> -TS

Predictions (d) and (e) were the only predictions born out both by RT data and accuracy rates and thus completely support subsection (c) of the Coda Law. The other predictions, which yielded less clear results, will be discussed below.

In order to highlight Li's horizontal and vertical comparisons, we have employed the notations shown in (15) to (19). In this notation, the elements contained within square brackets refer to the segments within the clusters being compared on a vertical or horizontal plane. The element at the top of the square brackets represents the most preferred complement to the element outside of the brackets (i.e., the cluster resulting in the lowest RT latency or highest accuracy rate). The relative preference for clusters decreases as one moves down the elements in the brackets. We will begin with the vertical comparison of coda-initial segments based on predictions (14a) and (14b).

The preference relations suggested in (14a) predict that a weaker coda initial segment would be easier to process. However, as we see in both the RT and accuracy data in (15), the Chinese-ESL subjects performed better with the clusters containing a coda-initial nasal. Li suggested that this was because the nasal-initial clusters are more in keeping with their native CV(N) type syllable structure.

(15) Results for Coda Prediction (14 a)

RT Latencies: $\begin{bmatrix} \mathrm{N} \\ \mathrm{L} \\ \mathrm{S} \\ \mathrm{T} \end{bmatrix} \mathrm{T}$ Accuracy Rates : $\begin{bmatrix} \mathrm{N} \\ \mathrm{S} \\ \mathrm{L} \\ \mathrm{T} \end{bmatrix} \mathrm{T}$

Like prediction (14a), prediction (14b) suggests that, coda initially, a weaker segment is preferred. The results for (14b) are represented in (16) .

(16) Results for Coda Prediction (14 b)

RT Latencies: $\begin{bmatrix} \mathrm{T} \\ \mathrm{L} \\ \mathrm{S} \\ \mathrm{N} \end{bmatrix} \mathrm{S}$ Accuracy Rates : $\begin{bmatrix} \mathrm{T} \\ \mathrm{N} \\ \mathrm{L} \\ \mathrm{S} \end{bmatrix} \mathrm{S}$

Based on the results in (16) it is impossible to define a clear trend in the data. However, it should be noted that syllable final /s/ often represents a morpheme. Hence, it is possible that the results Li obtained have been affected by the extraphonological influences of a subcontained morpheme.

Based on the findings in (15) we can conclude that weaker coda-initial segments are preferred. However, as we saw in (16) this basic preference may be altered by possible morphological influences (i.e., when syllable-final -s can be interpreted as a morphological marker). With this in mind we will now consider the horizontal comparisons of predictions (14c) and (14d) which focus on coda-final segments.

Prediction (14c), **-LT >> -LS >> -LN**, suggests that a stronger syllable-final segment is more preferred. The data obtained is represented in (17).

(17) Results for Coda Prediction (14c)

RT Latencies: $L\begin{bmatrix}N\\T\\S\end{bmatrix}$

Accuracy Rates : $L\begin{bmatrix}T\\S\\N\end{bmatrix}$

The results obtained from the accuracy data conform exactly to the original predictions in which a strong drop in Consonantal Strength towards the preceding nucleus is preferable (Coda Law (c)). However, the RT latency data were less conclusive.

The RT and accuracy data in (18) contradict the prediction, -TT >> -TS, in (14d).

(18) Results for Coda Prediction (14d)

RT Latencies: $T\begin{bmatrix}S\\T\end{bmatrix}$

Accuracy Rates : $T\begin{bmatrix}S\\T\end{bmatrix}$

Given the contradictory results obtained from the comparisons in (14b) and (14c) which were attributed to the extraphonological influences of orthographic frequency and morphological structure, Li was not surprised that the -TS cluster generated lower RT's and higher accuracy rates than was originally predicted.

In general, we can conclude that Li's findings in (15) to (18) are in keeping with the predictions in (14c) to (14f). That is to say, subjects tended to respond more quickly to stimuli with a weak coda-initial segment and a strong coda-final segment. Hence, subsection (c) of the Coda Law was supported. However, when the extraphonological influences of orthographic frequency and morphology came into play (e.g. predictions 14a, 14b, and 14f) we saw that these extraphonological influences could significantly affect the data obtained for each measure. Consequently, the variability of Li's data can be attributed to the extraphonological influences for which she failed to control.

The fact that Li was able to identify the effects of syllable configurations, despite the extraphonological influences, attests to the robust nature of the claims of Preference Theory. Therefore, if we could effectively control the extraphonological influences and devise a more refined means of investigating the interactive effect of consonantal and positional strengths, then we should be able to identify the effects of the principles and parameters of Preference in language processing more clearly.

Based on our re-analysis, we suggest that it was (a) the categorial investigation of diconsonantal clusters which limited the scope of Li's study and (b) the problems associated with morphological influences and intrasubject variability which compromised the reliability of the RT latencies. In order to move beyond these inadequacies it is necessary to (a) establish more stringent controls for extrasyllabic influences; (b) sample a larger range of stimuli; (c) employ a more homogeneous population, and (d) develop a more powerful and precise evaluation metric. The detailed re-analysis of Li's predictions, design and data was of great value in the design of our evaluation metric discussed in Section 2.3 and our research methodologies presented in Chapters 3 & 4.

2.3 A Calculus Based Operationalization

We began the operationalization process by defining the acceptable range of graphemic representations. Based on Clements, Sheldon and Cookshaw (1990) we identified the phonemes which can be consistently represented monographemically. Consequently, our grapheme pool was limited to the following segments which exhibited a one-to-one grapheme-to-phoneme correspondence (i.e.{**b, d, f, g, k, l, m, n, p, r, s, t, v, z; i, a**}[1]) which falls within the categories defined by Vennemann's Consonantal Strength Scale in Figure 1.6.

In Vennemann's Consonantal Strength Scale, voiced stops and voiceless fricatives are grouped together; however, we chose to treat them separately because this would allow us to investigate the finer distinctions and effects of manner of articulation more effectively. Consequently, we assigned a numeric strength value to each class of segments, which resulted in The Refined Consonantal Strength Scale in Figure 2.5 (based on Vennemann 1988: 9).

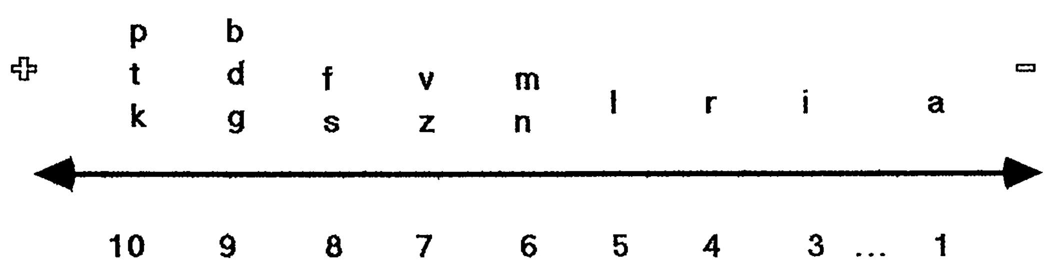


Figure 2.5 - The Refined Consonantal Strength Scale

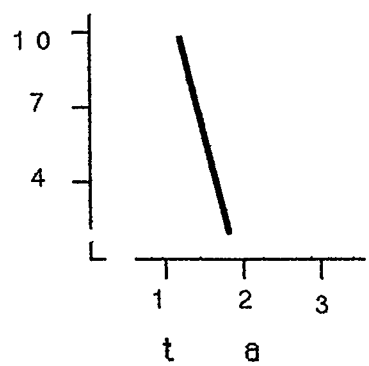
Given the numeric assignments in Figure 2.5 it becomes possible to describe the characteristics of Terminal Constituents in terms of the rate and direction of change in Consonantal Strengths from one segment to the next. The rate and direction of change between two segments will be referred to as Slope.

1 Since our investigation focuses on the Preference Laws affecting Terminal Constituent clusters we have limited our vowel inventory to {a, i} which were intended to represent the ideal extremes of the vocalic range.

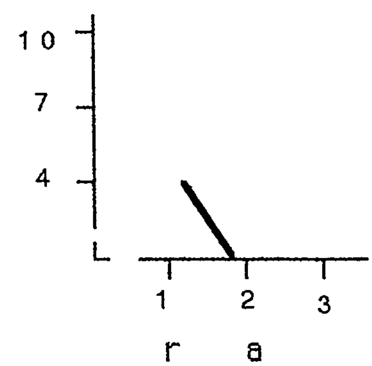
The notion of Slope can be illustrated using monoconsonantal heads and codas in relation to the syllable nucleus. For example, in (19a) we can see that the Slope generated by a syllable-initial /t/ to a vowel is steeper (i.e. sharper) than the Slope generated by a syllable-initial /r/ to a vowel (19b).

(19) Basic slopes generated by a syllable-inital:

a) voiceless stop (i.e. /p, t, k/)



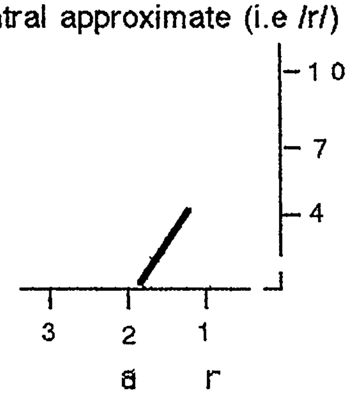
b) central approximate (i.e /r/)



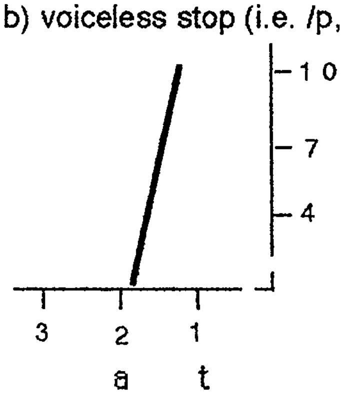
Likewise,in (20b) we can see that the Slope generated by a syllable-final /t/ to the preceding vowel is steeper (i.e. sharper) than the Slope generated by a syllable-final /r/ to the preceding vowel (20b).

(20) Basic slopes generated by a syllable-final:

a) central approximate (i.e /r/)



b) voiceless stop (i.e. /p, t, k/)



It is important to note that the notion of Slope allows us to characterize syllabic configurations without specifying whether they are more or less preferred than some other configuration. We suggest that it is possible to operationalize Vennemann's formulation of the Head and Coda Laws in terms of Slope, where the Preference Laws identify whether or not the Slope for a given configuration is to be identified as more or less preferred.

The notion of Slope is central to the formulation of our evaluation metric (Libben 1989) which has been developed in order to assign a Slope Value (SV) to heads and codas based on the configurations of the consonantal elements within these domains. In the following sections, this metric is discussed in terms of the domain specific applications (i.e. head and coda) for the mono-, di-, and tri-consonantal clusters we have employed in our study.

2.3.1 Head Evaluation

The Slope Value of a multiconsonantal head is derived from the interaction of the sum of the differences in consonantal strength of adjacent consonants (moving left to right) (i.e. $\Sigma(L\text{-}R)$) divided by the number of adjacent consonants in the head (A). In other words, the head evaluation calculates a Slope Value based on the Composite Differential Strength Value (CDSV) (i.e. $\Sigma(L\text{-}R)$) over a given distance (A).

$$\mathbf{SV(head)} = \frac{\mathbf{CSDV}}{\mathbf{\#\ of\ C\ pairs}} = \frac{\Sigma\mathbf{(L - R)}}{\mathbf{A}}$$

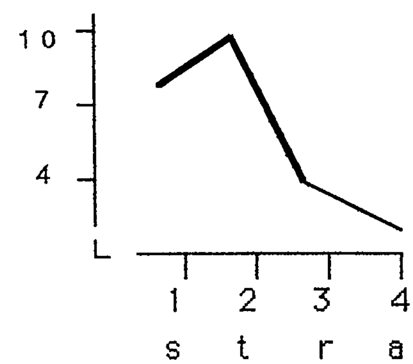
Figure 2.6 - The Head Evaluation Metric

Examples (21 a-b) depict the Slopes and calculation of Slope Values for di- and triconsonantal heads. In the Slope diagrams the heavy line refers to the range of the Slope Value calculation and the lighter line refers to the transition from the head or the coda to the nucleus of that syllable. The lighter line has been included for the sake of completeness in terms of the descriptive formulations of the Head and Coda Laws.

(21) Head Evaluations

(a) The Triconsonantal /str/ Head:

The Slope:

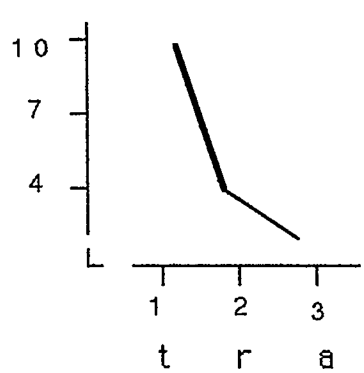


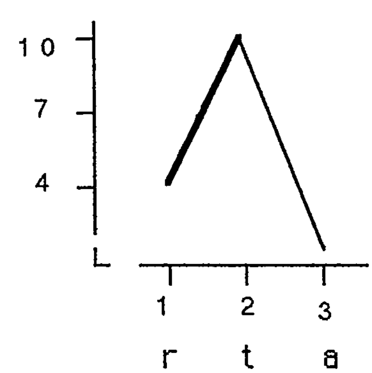
The Calculation of the Slope Value:

$$H = SV(str) = 8\ 10\ 4 = \frac{(8 - 10) + (10 - 4)}{2} = 2$$

(b) Diconsonantal Heads

The slopes for /tr-/ and /rt-/:





The Calculation of the Slope Values:

$$H = SV(tr) = 10\ 4 = \frac{(10 - 4)}{1} = 6$$

$$H = SV(rt) = 4\ 10 = \frac{(4 - 10)}{1} = -6$$

Monoconsonantal heads are assigned a Slope Value which is directly proportional to their Consonantal Strength values because because for these heads R and A are always equal to 0. Hence the Slope Value would be undefined.

Based on the evaluation metric , Table 2.1 illustrates that the Slope Values for diconsonantal heads range from -6 to 6. If we compare this with the range for monoconsonantal segments, we find that except for /l/ and /r/, a monoconsonantal head will generate a higher Slope Value.

$$SV(C_L C_R) = \frac{\Sigma(C_L - C_R)}{1}$$

		Right						
		10	9	8	7	6	5	4
	10	0	1	2	3	4	5	6
	9	-1	0	1	2	3	4	5
	8	-2	-1	0	1	2	3	4
Left	7	-3	-2	-1	0	1	2	3
	6	-4	-3	-2	-1	0	1	2
	5	-5	-4	-3	-2	-1	0	1
	4	-6	-5	-4	-3	-2	-1	0

Table 2.1 - Head Evaluations for Diconsonantal Combinations

2.3.2 Coda Evaluation

A similar approach was taken to the operationalization of the coda evaluation. The Slope Value for the coda is derived from the sum of the differences in Consonantal Strength of adjacent consonants (moving from right to left) (i.e. $\Sigma(R-L)$) divided by the number of consonant pairs (A). Monoconsonantal codas are also assigned a SV equal to their consonantal strength.

$$\mathrm{SV(coda)} = \frac{\mathrm{CSDV}}{\#\text{ of C pairs}} = \frac{\Sigma(R - L)}{A}$$

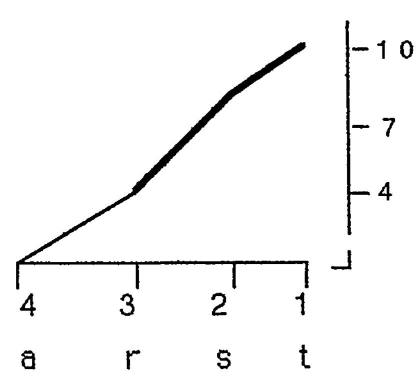
Figure 2.7 - The Coda Evaluation Metric

Examples (22 a-b) depict the relative slopes of and the calculations of the SV for di- and triconsonantal syllable-final clusters permitted in English.

(22) Coda Evaluations

(a) The Triconsonantal /-rst/ Coda

The Slope:

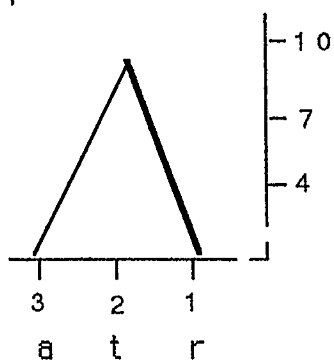


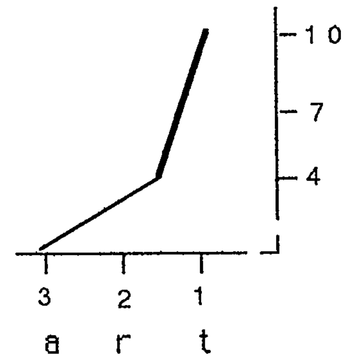
The Calculation of the Slope Value for /-rst/ :

$$C = \mathrm{rst} = 4\ 10\ 8 = \frac{(8 - 4) + (10 - 8)}{2} = 3$$

(b) Diconsonantal Codas

The Slopes for /-tr/ and /-rt/:





The Calculation of the Slope Values:

$$C = \quad SV(rt) = 4 \ 10 = \frac{(10 \ - \ 4)}{1} = 6$$

$$C = \quad SV(tr) = 10 \ 4 = \frac{(4 \ - \ 10)}{1} = -6$$

Based on the evaluation metric for diconsonantal codas, Table 2.2 illustrates that the Slope Values range from -6 to 6. Furthermore, as we saw with the head evaluations, except for /l/ and /r/, a monoconsonantal coda will generate a higher Slope Value (i.e. 4 to 10).

$$SV(C_L C_R) = \frac{\Sigma(C_R \ - \ C_L)}{1}$$

		Right						
		10	9	8	7	6	5	4
Left	10	0	-1	-2	-3	-4	-5	-6
	9	1	0	-1	-2	-3	-4	-5
	8	2	1	0	-1	-2	-3	-4
	7	3	2	1	0	-1	-2	-3
	6	4	3	2	1	0	-1	-2
	5	5	4	3	2	1	0	-1
	4	6	5	4	3	2	1	0

Table 2.2 - Coda Evaluations for Diconsonantal Combinations

It is important to note that there are two key differences between Vennemann's formulations of the Preference Laws and the evaluation metric's operationalization of the Preference Laws. First, Vennemann refers to drops in Consonantal Strength in relation to the nucleus of the syllable. However, in the formulation of the evaluation metric consonantal elements, only, are taken into consideration. Given that our experiments hold vowels constant this difference does not affect our evaluation of the data. Hence, our use of the evaluation metric represents a collapsation of the Preference Laws because it characterizes the interactive effects of the length and composition (i.e. types and order of consonantal elements) of each domain.

Second, given that the evaluation metric assigns a Slope Value of -2 to /sp/, /st/ and /sk/ heads and a Slope Value of 2 to /spr/, /skr/ and /spr/ heads, the evaluation metric characterizes the relationship between these head configurations differently than the proponents of Preference Theory (cf. Murray 1990). In fact, Libben suggests that Slope Values correspond directly with the relative Preference for a given configuration (i.e. " A syllabic configuration is more preferred the greater the Slope"). Although it is possible to adopt either point of view from the outset of our experiment, it is not necessary. That is to say, the empirical results can determine the accuracy of their positions. Therefore, we can make the following sets of predictions based on each of the perspectives:

(23) Predictions Based on Libben's Perspective :

Subsyllabic configurations which result in higher Slope Values are easier to process. Therefore, subsyllabic configurations with higher Slope Values will generate lower response time latencies.

(24) Predictions Based on Vennemann's Perspective :

Head Predictions

a) C >> CC >> CCC

b) a head will be more preferred, the greater the SV

Coda Predictions

a) C >> CC >> CCC

b) a coda will be more preferred, the lower the SV

c) a coda will be more preferred, the greater the SV

Consequently, if Libben's view is correct, then lower RT latencies should correspond with subsyllabic configurations having higher SV's. If, however, Vennemann's views are correct, then heads with a high SV should generate low RT's and codas with high SV's could generate either high or low RT's. If, however, both views are incorrect and Preference plays no role in language processing or in the characterization of the preferred nature of syllabic configuration, then the statistical evaluations of the response time data that we have obtained will either contradict the predictions or they will fail to identify significant differences. During the course of our experimental investigations we will identify the data which supports or opposes these views as we move towards a better understanding of the role of Preference Theory in language processing.

Chapter 3

Phonotactic Constraints & The Preference Laws

The design of the experiment reported below has been guided by a consideration of many of the issues discussed in Chapter 2. In particular, this experiment investigates a wider range of head and coda configurations in terms of both length and composition than that of Li (1989). Also, as has been discussed in Section 2.3, our use of the Slope Value evaluation metric allows for greater precision in the formulation of our hypotheses and the analysis of our data.

In this experiment, we address the question: "Will differences in Slope Values affect subjects response times to nonsense monosyllables which conform to the phonotactics of English?" If Slope affects response latencies then the analysis of the effect will identify whether or not the preference relations embodied in the Preference Laws govern this level of language processing. If, however, the effects of Slope do not conform to the Preference Theory predictions, then one of three possibilities exists. First, the formulation of our evaluation metric would be inaccurate. Second, the formulation of the Preference Laws may be incorrect, in which case Libben's position (i.e. the greater the Slope the better) may be supported. Or finally, that subsyllabic configurations do not play a significant role in language processing. These alternatives are empirically verifiable given the design and scope of our experiment.

3.1 Experimental Design

3.1.1 Subjects (n=37)

The subjects in this experiment were 14 males and 23 females with an average age of 27.4 years recruited from the staff and students of the University of Calgary. All subjects:

(a) possessed normal or corrected to normal vision;

(b) were right handed;

(c) demonstrated an adequate oral reading ability, and

(d) were monolingual speakers of English.

3.1.2 Procedure & Apparatus

In this experiment subjects were asked to read aloud a series of tachistoscopically presented non-words from the screen of a laptop computer. Participants were asked to give their best approximation of the pronunciation of each non-word stimulus and to guess when uncertain.

At the beginning of each experiment, the subject was informed of the nature and the purpose of the experiment (i.e. the investigation of pronunciation errors. Each experimental session began with the subject adjusting the contrast of the computer screen to his or her liking. When the subject was ready, he or she was asked to begin the experiment by pressing the "Enter" button.

Each experimental session consisted of a ten-trial warm-up period and 148 experimental trials. Each trial, as depicted in Figure 3.1, began with a warning beep which was followed by the visual warning "Prepare for Stimulus". The stimulus was then flashed in the center of the screen.

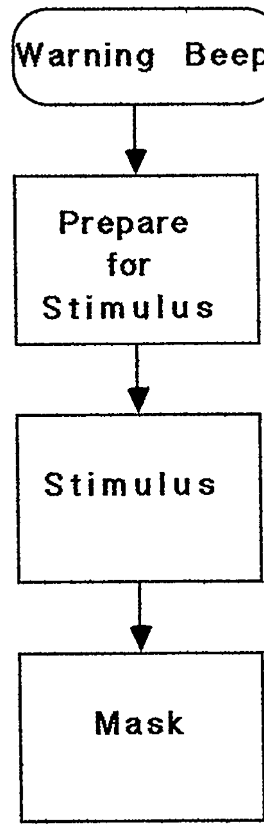


Figure 3.1 - A Sample Trial

Subsequent trials were voice-cued from the beginning of the preceding response.

This experiment was run on a Tandy TRS 80 Model 100 laptop computer with a liquid crystal display screen. Consequently, it was necessary to employ a a post-stimulus pattern mask to counteract the slow character decay associated with these screens.

The flow of the experiment was controlled by a program (Libben 1989), written in BASIC, which was designed to:

(a) present a common pre-test consisting of ten sample stimuli;

(b) randomize the beginning point within the actual stimulus set ;

(c) control the activation of the tape recorder;

(d) record the response times (RT was calculated by a machine-language subroutine which was accurate to 4 milliseconds).

In addition to the laptop computer, our hardware included a Radio Shack Electric Condenser 600 OHMS microphone, a Sanyo M1010 tape recorder and a voice key mechanism[1]. Scotch BX 90 Pos 1 casette tapes were used to record the sessions.

Data collected during the experiment was in two forms, responses and response times. As each stimulus flashed on the screen, the subject's first response was transcribed by the experimenter. Responses were recorded as either "correct" or as a loose transcription of the "incorrect" response. Responses were judged "correct" or "incorrect" based on an idealized phonetic pronunciation of each stimulus. The transcriptions were supplemented with a tape recording of each session. The original transcriptions were randomly verified against the tape recordings in order to ensure the accuracy of the data obtained.

3.1.3 Stimuli

We decided to test a wider range of syllabic configurations than Li (1989) in order to facilitate our investigation of the interactive effects of Stimulus Length, Consonantal Strength and Slope relations which form the basis of our evaluation metric. Consequently, our stimuli were constructed from a $C_1^3VC_1^3$

---

[1] This device was designed and built by Technical Services, University of Calgary.

template which represents the maximal range of English syllabic configurations which containing both a head and a coda.

The two major factors taken into consideration during the development of our stimuli were the control of semantic inferences and orthographic influences. First, it was necessary to avoid sequences which could be interpreted as having a homophonous real-word or morphemic counterpart. Hence, we avoided configurations such as blud (c.f. blood).

Second, in order to minimize the influences of orthographic knowledge it was necessary to constrain our graphemic representations to those letters which bear a direct one-to-one correspondence with their phonemic counterparts. Therefore, based on Clements, Sheldon and Cookshaw (1990), we identified the transparent mono-graphemic representations permissible in English. The grapheme pool in (25) represents the range of consonants from which we could construct our syllabic configurations.

(25) The Grapheme Pool

< b, d, f, g, k, l, m, n, p, r, s, t, v, z >.

In addition to constraining our grapheme-pool, we also limited the co-occurrence of graphemes within a stimulus. Hence, sequences which could be misconstrued as morphemes were not included. For example, we avoided stimulus final < s >, < d > and < t > which can function as person, tense or possessor markers. Therefore, our mono-syllabic non-word stimuli were further constrained to be mono-morphemic as well.

Given our constraints, we found that all single consonants can occur as either a head or a coda in English. However, the occurrence of triconsonantal clusters in monomorphemic roots is restricted to **< str, skr, spr, spl >** for heads and only **< rst >** for codas. Tables 3.1 & 3.2 demonstrate the acceptable diconsonantal heads and codas in English which we were able to construct. It should be noted, that the acceptable combinations we constructed do not include borrowed combinations such as /ts-/ from words like tsi-tsi fly.

C2

C1	p	t	k	b	d	g	f	s	v	z	m	n	l	r
p								x						x
t														x
k													x	x
b													x	x
d														x
g													x	x
f										x				x
s	x	x	x								x	x	x	
v														
z														
m														
n														
l														
r														

Table 3.1 - Acceptable Diconsonantal Heads in English

		C2													
		p	t	k	b	d	g	f	s	v	z	m	n	l	r
	p														
	t														
	k														
	b														
	d														
	g														
C1	f		x												
	s	x	x	x											
	v														
	z														
	m	x													
	n		x	x											
	l	x	x	x	x	x		x		x		x	x		
	r	x	x	x	x	x	x	x		x		x	x	x	

Table 3.2 - Acceptable Diconsonantal Codas in English

Given the phonotactic constraints of English our range of possible head and coda configurations is limited. This range actually represents a small subset of all the possible combinations which can be formed from the graphemes in our grapheme-pool (25).

It is interesting to compare the heads and codas which are acceptable in English with the Slope Values in Tables 2.2 & 2.3. Acceptable heads fall within the Slope Value range of -2 to 6. The acceptability of the negative Slope Values for diconsonantal clusters containing syllable initial /s/ attests to the special status attributed to syllable initial /s/'s. Acceptable codas occur within the 1 to 6 range of Slope Values.

It is possible to construct the Slope Value Scales in Figures 3.2 & 3.3 for diconsonantal heads and codas, where the diconsonantal clusters occurring on the high end of the scales should generate lower RT's than those occurring on the low end of the scales.

−	-2	//	2	3	4	5	6	+
	sk		sm	fl	bl	br	kr	
	sp		sn	sl	gl	dr	pr	
	st				fr	gr	tr	
						kl		
						pl		

Figure 3.2 -

Slope Value Scale for English Diconsonantal Heads

−	1	2	3	4	5	6	+
	lm	ft	lf	lb	lk	rk	
	ln	sk		ld	lp	rp	
	rl	sp		mp	lt	rt	
		st		nk	rg		
		rm		nt	rb		
		rn		rf	rd		
		lv					

Figure 3.3 -

Slope Value Scale for English Diconsonantal Codas

In contrast with Li's descriptive analysis, our comparison of clusters has been simplified by the use of our evaluation metric. Our metric generates a continuous range Slope Values. Hence, it is possible for us to compare all cluster types, unlike Li who was restricted to the vertical or horizontal comparisons.

Based on the range of acceptable graphemic combinations, a head or coda was paired with a complement randomly drawn from each Slope Value level. For example, in Figure 3.4, the triconsonantal head, /str/, would be randomly paired with either /a/ or /i/. Then a random compliment, or in this case a coda, was selected from each Slope value level.

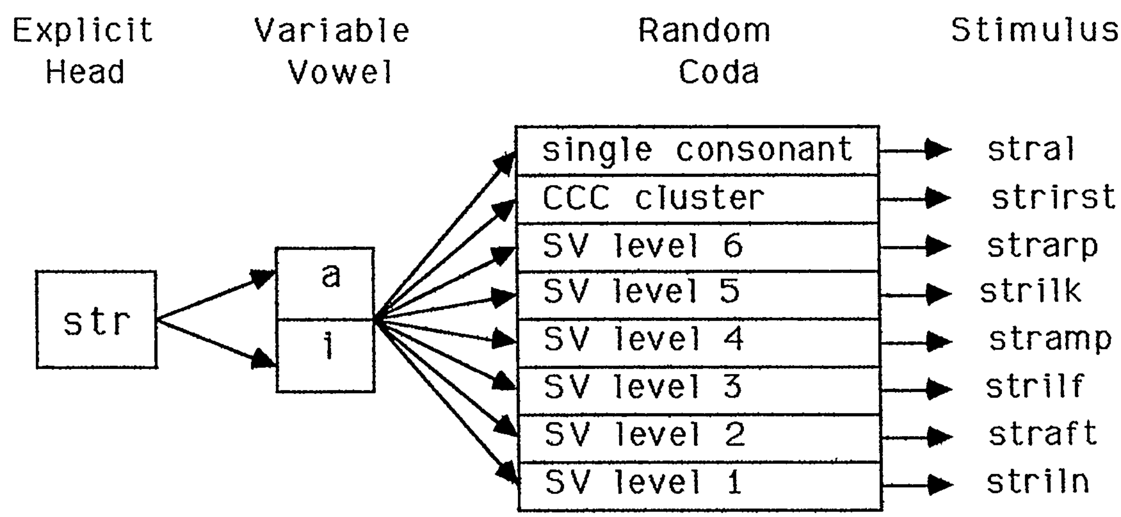


Figure 3.4 - The Stimulus Selection Process

This process ensured that all possible graphemic representations of heads and codas were explicitly represented and that complement types were equally and randomly represented. Stimuli were randomly ordered, with the actual stimulus list is represented in Table 3.3.

TP0.	skral	29.	kilk	70.	fik	111.	laz
PT1.	rir	30.	prasp	71.	drirn	112.	bilp
PT2.	blint	31.	darf	72.	splirk	113.	strarst
PT3.	sprag	32.	smarv	73.	kif	114.	barl
PT4.	prirst	33.	kir	74.	galn	115.	krisk
PT5.	vint	34.	nirm	75.	slirst	116.	sim
PT6.	splist	35.	sprirst	76.	dramp	117.	klirf
PT7.	rarn	36.	paft	77.	splarst	118.	sprirt
PT8.	farst	78.	stip	37.	lan	119.	tid
PT9.	blig	38.	stralk	79.	marst	120.	splim
		39.	frist	80.	prirl	121.	strit
		40.	grilp	81.	fank	122.	plap
		41.	straft	82.	splarn	123.	flalm
1.	plarb	42.	lilf	83.	varb	124.	spaft
2.	flink	43.	pim	84.	fap	125.	firt
3.	frarp	44.	dirst	85.	skalf	126.	smilm
4.	riv	86.	blarg	45.	sprimp	127.	flisk
5.	drask	46.	kip	87.	zalt	128.	lir
6.	fraf	47.	slisp	88.	gralv	129.	skrat
7.	skralf	48.	talm	89.	plim	130.	sald
8.	sif	49.	rarst	90.	stirf	131.	dris
9.	skarst	50.	smir	91.	nal	132.	pral
10.	klig	51.	brild	92.	skrard	133.	krild
11.	lirp	52.	lirp	93.	tast	134.	stirm
12.	slaz	53.	mim	94.	girg	135.	bis
13.	trink	54.	sprilp	95.	falp	136.	blamp
14.	zark	55.	lirst	96.	klirl	137.	fliv
15.	snard	56.	dimp	97.	smarp	138.	sparm
16.	plart	57.	trilt	98.	brip	139.	glirv
17.	miv	58.	friln	99.	trav	140.	spid
18.	stralm	59.	blad	100.	skrant	141.	pib
19.	sab	60.	skraz	101.	nir	142.	krat
20.	flarst	61.	lig	102.	snad	143.	stirb
21.	gral	62.	skrist	103.	nis	144.	glin
22.	splis	63.	glalt	104.	zirst	145.	snirv
23.	glant	64.	nilb	105.	bramp	146.	baz
24.	klalv	65.	splilv	106.	skak	147.	skak
25.	lal	66.	garg	107.	blalb	148.	nin
26.	pilv	67.	gralk	108.	tirg		
27.	brirst	68.	brift	109.	mib		
28.	sar	69.	smarst	110.	risp		

Table 3.3 - Stimulus List #1

As has been discussed above, the design of this experiment has made it possible to test not only the predictions of the Preference Laws in general but to also investigate the specific factors that may determine RT in this task. We note that our independent variable SV, actually is composed of the factors CSDV and adjacencies. In this experiment we have attempted to probe the role of each of these factors in language processing. The distinctness of these factors is shown in Figures 3.5 and 3.6.

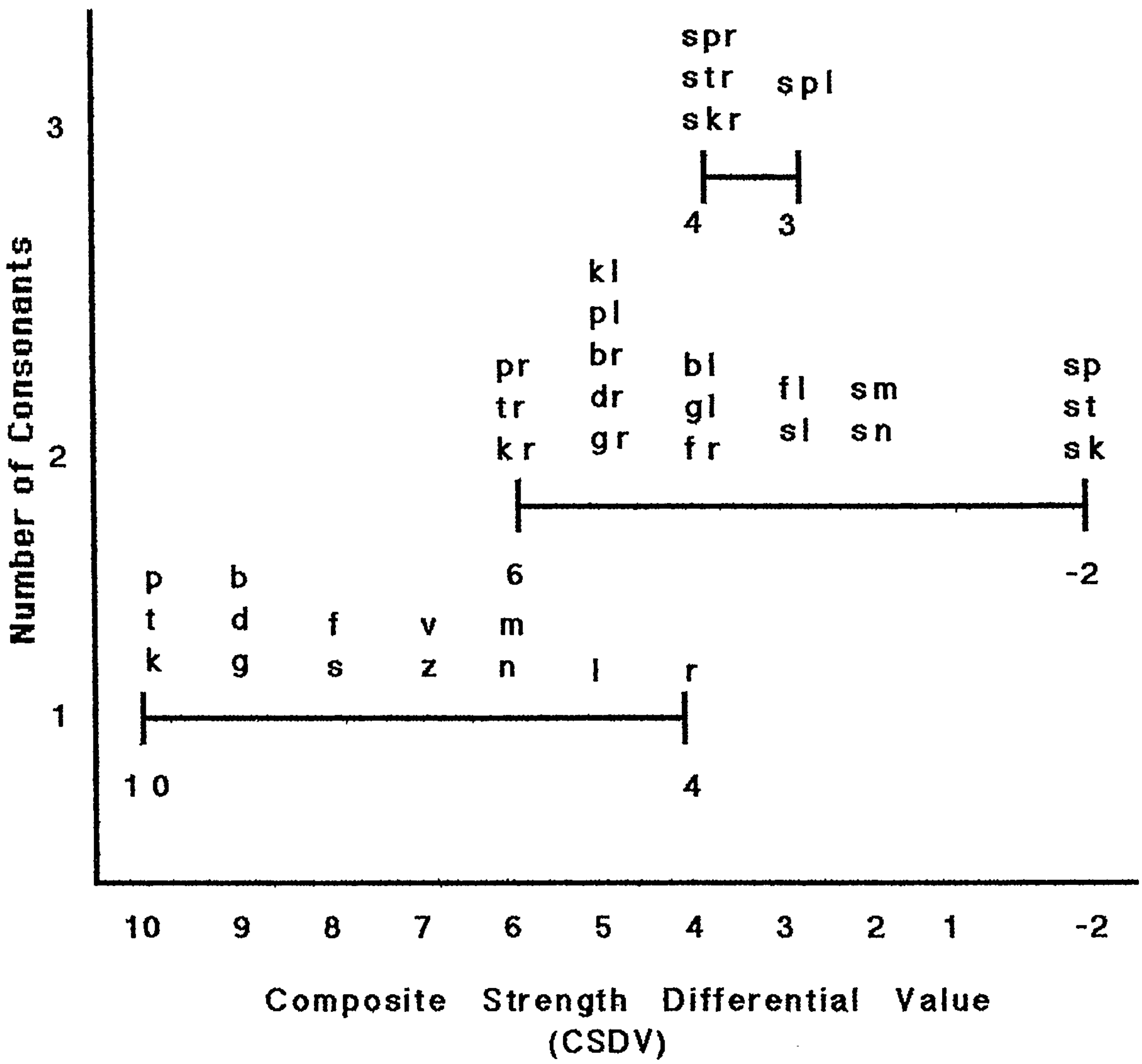


Figure 3.5 - Composite Slope Scale for Heads

and adjacencies. In this experiment we have attempted to probe the role of each of these factors in language processing. The distinctness of these factors is shown in Figures 3.5 and 3.6.

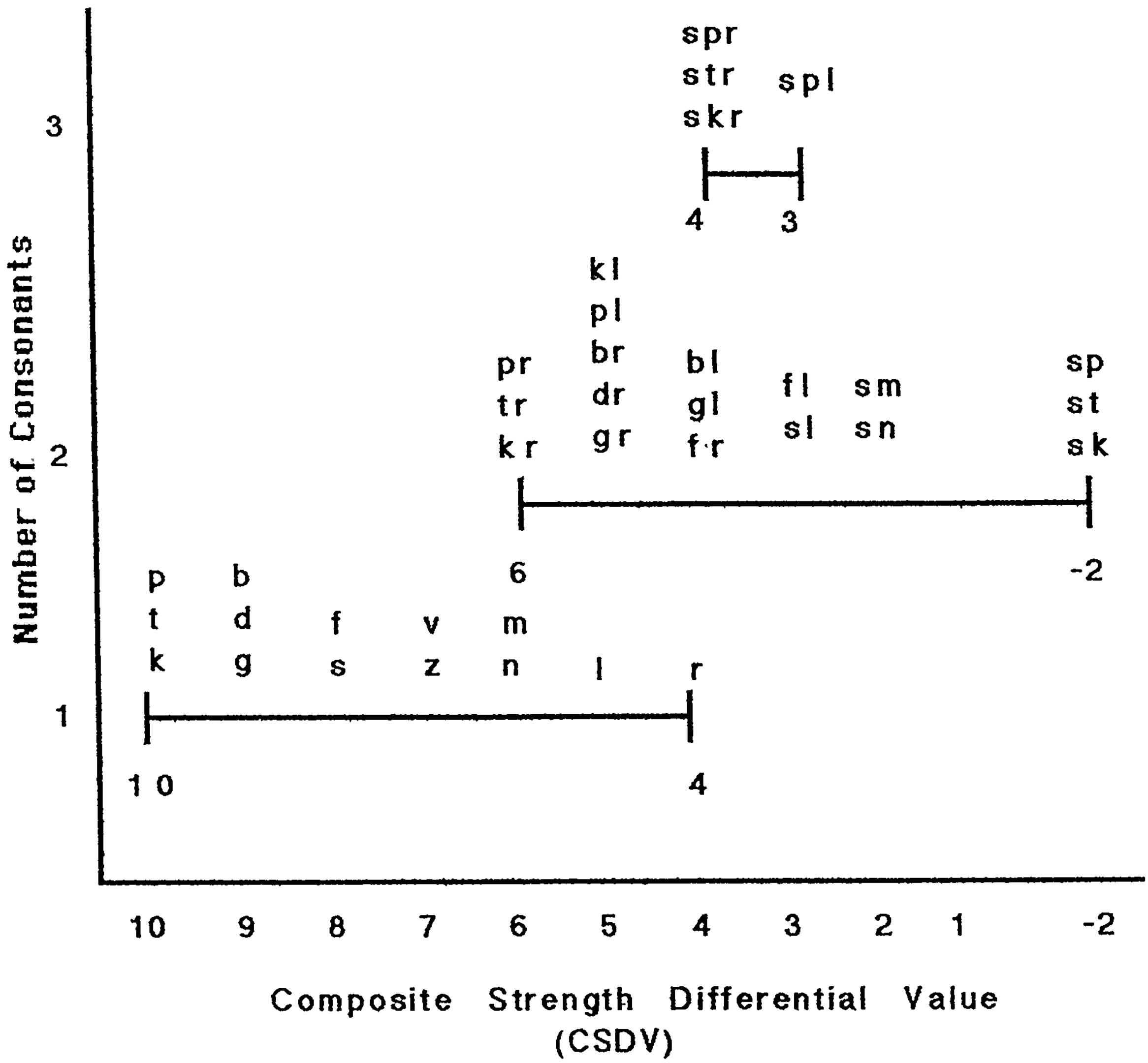


Figure 3.5 - Composite Slope Scale for Heads

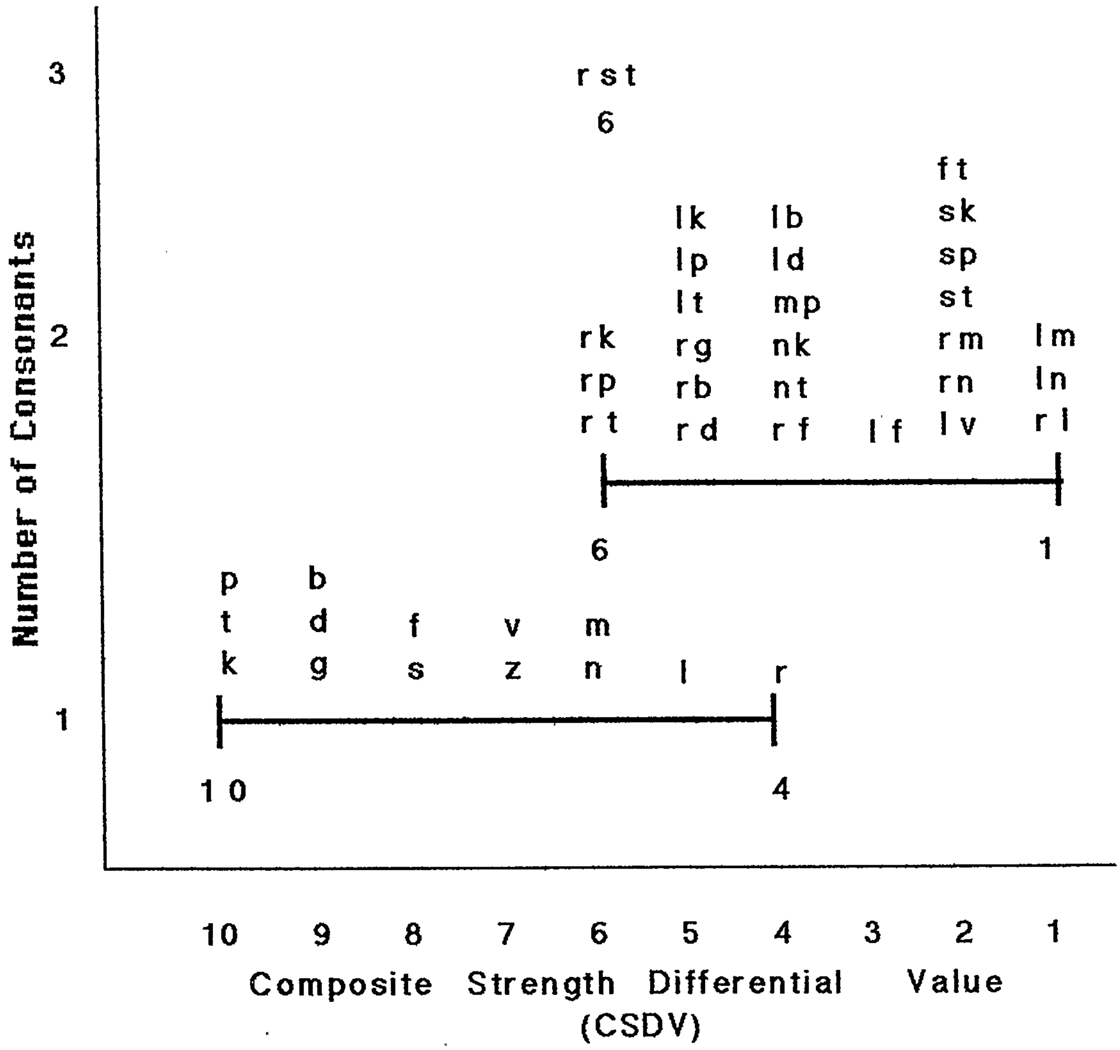


Figure 3.6 - Composite Slope Scale for Codas

It is important to note that before Length is factored into the calculation of the SV, the CSDV of triconsonantal clusters is relatively high. The interactions highlighted in these figures form the basis of our evaluation metric and the investigation of these factors forms the basis of our empirical investigation into the role of Preference Theory in language processing which is detailed in the final section of this chapter.

3.2 Analysis of Response Time Latencies

Our analysis of the response time latency data began with a validation of our measures and method because RT latencies were calculated from the beginning of a subject's response. Hence, as Li noted, it is possible that the latencies which were recorded would not be a valid measure of the processing time (i.e. if a subject's response was preceded by a false start or a subject's response contained a pause). Therefore, our preliminary analysis investigated the relationship between RT latencies for Stimuli, Heads and Codas of different Lengths. Length is equal to the number of phonemes in the configuration because there is a direct grapheme-to-phonoeme correspondence.

A one-way ANOVA revealed an overall effect for Stimulus Length ($F_{4,33}= 66.54$; $p< .001$), Head Length ($F_{2,35}= 172.49$; $p< .001$) and Coda Length ($F_{2,35}= 47.59$; $p< .001$). The data revealed that the longer the configuration, the longer the RT latency. For Length to have a significant effect on RT latencies, subjects must have processed an entire stimulus before responding. Hence, we take response time latencies to be a valid measure of overall processing and conclude that the use of this fine measure in our study is methodologically sound.

However, the fact that RT's were shown to be significantly affected by the Length of a Stimulus, Head and Coda raises the very important theoretical question: "Are subjects' responses affected by the Slope of a given configuration or are subjects' responses solely affected by the Length of a Head or Coda?" The investigation of this question is crucial to our investigation of the role of Preference in language processing. That is to say, if the RT data indicates that the Length of a Head or Coda alone is the primary factor affecting RT latencies, then we would have to conclude that the role of the other factors which contribute to the formulation of the Preference Laws and the evaluation metric is negligible in language processing.

In our analysis we will consider each of these factors. Our analyses for heads and codas begin with an investigation the effect of SV's on the RT latencies. Then we consider the effect of CSDV on heads and codas of a fixed Length. And finally, we consider the effect of CSDV on heads and codas of a fixed Length with complements of a fixed Length. This three stage analysis makes it possible to hold an increasing number of influences constant while investigating the effect of the remaining factors on RT's.

3.2.1 Head Evaluations

Our evaluation metric generates Slope Values for monoconsonantal heads which range from 4 to 10, for diconsonantal heads which range from -2 to 6, while triconsonantal heads evaluate as either 1.5 or 2.

3.2.1.1 The Effects of Slope Value

Based on SV's we grouped the head configurations into three levels, high (SV 7 to 10), mid (SV 1.5 to 6) or low (SV -2). The heads which fall within the high range of SV's represent monoconsonantal head configurations only. Mid level heads can be of any Length. And low level heads represent those diconsonantal clusters which contain the exceptional syllable initial <u>s-</u>. Given the predictions in (23) and (24), we would expect that response time latencies should be the shortest for the high level heads and the longest for the low level heads.

Based on these groupings, a one-way ANOVA revealed an overall effect for SV level ($F_{2,35}$= 47.27; p< .001). A post-hoc Scheffe F-test demonstrated significant differences between all three levels (p< .05). As can be seen in Table 3.4 the results indicate that effects of Slope Value are in the predicted direction (i.e. RT latencies are the shortest for the high level heads and the longest for the low level heads).

SV Level	RT (ms)
High (7-10)	633.74
Mid (1.5-6)	704.63
Low (-2)	759.31

Table 3.4 - The Effects of Slope

Furthermore, the "exceptional" low level heads exhibit the highest RT latency. Recall, however, that Li's study was unable to find this predicted effect in either RT or accuracy. Based on the differences between the Vennemannian formulation of the Preference Laws and the operationalization of the Preference Laws in Section 2.3, this finding is as would be predicted based on the operationalization of the Preference Laws, but it is counter to the expectations of the proponents of Vennemannian theory (Murray 1990).

In general, our findings imply that, in addition to Length, Slope also affects response time latencies. Therefore, we concluded that the configuration of the head does come into play during language processing. Hence, we suggest that RT latencies are an effective means of measuring the effects of more or less preferred head Slopes and that these effects support the predictions based on the operationalized Vennemannian Theory in (23) and Libben's evaluation metric in (24).

3.2.1.2 The Effects of CSDV

Given that our initial analyses identified an effect for both Head Length and SV, we began a more systematic exploration of the overall effects of the factors contributing to Slope. As was mentioned at the beginning of Section 3.2, the next step in our analysis was to isolate the CSDV's holding Head Length constant. In this analysis heads were first grouped by Length (i.e. C, CC, or CCC) and then subgrouped by CDSV. Consequently our data was arranged as follows:

a) monoconsonantal heads with CSDV's from 6 to 10

b) diconsonantal heads with CSDV's from 2 to 6 and -2

c) triconsonantal heads with CSDV's of 3 and 4

A one-way ANOVA revealed an overall effect for the CSDV of monoconsonantal heads ($F_{6,35} = 21.53$; $p < .001$) and diconsonantal heads ($F_{3,35} = 9.89$; $p < .001$). However, the triconsonantal head analysis, which compared a CSDV of 4 with a 3, failed to yield a significant difference ($p = .513$).

Given that an increase in length or a decrease in CSDV both serve to reduce the Slope Value for a given configuration. We would expect that as the CSDV for a given head length decreases, the RT latency increases. Furthermore, as the length of the head increases so should the RT latencies (i.e. based on our predictions in (23) and (24)).

However, the mean RT's obtained and the results from our analyses suggest that the interaction between RT, length, CSDV, and SV are not as straight-forward.

Head Length	CSDV	RT (ms)
C	10	649.31
C	9	617.66
C	8	658.71
C	7	609.30
C	6	568.68
C	5	575.06
C	4	583.96
CC	6	686.14
CC	5	730.10
CC	4	681.06
CC	3	713.87
CC	2	676.15
CC	-2	759.31
CCC	4	809.44
CCC	3	822.44

Table 3.5 - The Effects of CSDV

In fact, if we consider the RT data in Table 3.5 and the post-hoc analyses, we find that four general trends emerge. First, the data Table 3.5 shows that subjects took longer to respond to monoconsonantal heads with high SV's. This is opposite to the predictions in (23) and (24). Over the range of CSDV's for monoconsonantal heads the differences in RT latencies were shown to be significant ($F_{6,35}$= 21.53; $p < .001$). And a post-hoc Scheffe F-test revealed that the significant differences resulted when the CSDV of the heads differ by at least two levels ($p < .05$). Hence, this data contradicts the predictions.

The second trend which emerges concerns diconsonantal head clusters. Once again a one-way ANOVA revealed an overall effect for CSDV's ($F_{5,35}$= 9.89; $p< .001$). Although the raw RT's in Table 3.5 indicates a general trend in support of the expected inverse relation between CSDV and response time latencies exists, a Scheffe F-test revealed that the majority of the significant differences identified exist between the exceptional head types (i.e. -2 CSDV) and all other diconsonantal clusters ($p< .05$).

The third observation which can be made concerns the relation between the RT latencies of mono- and diconsonantal heads with the same CSDV. The data in Table 3.5 indicates that the diconsonantal heads with the CSDV's of 4 to 6 generated longer RT latencies than did the monoconsonantal heads with the same CSDV range. Hence, we have further evidence that both the Length and the CSDV of a subsyllabic configuration affects language processing.

This finding also highlights the fourth general trend which suggests that response time latencies are being affected by more than the Slope Value or the CSDV for a given head. Hence, we must consider the potential effects of the complement (i.e. Length and composition of the coda).

3.2.1.3 The Effects of Complement Length

If RT latencies for a given head are affected by more than the SV or CSDV, then there are two primary avenues which need to be explored. Either the length of the coda, or the CSDV of the coda, may be affecting processing times.

We decided to explore the first possibility for two reasons. First, the re-evaluation of the head types in Table 3.5 in terms of the SV of the coda would yield a very sparse comparison matrix. Consequently, the statistical validity of a comparison of RT latencies based on a head of fixed length and its CSDV, with a coda of a fixed SV would be compromised.

Second, given the significant results concerning the overall effect of Stimulus, Head and Coda Length obtained in our initial analyses it is highly probable that Complement Length alone could be the contributing factor. Consequently, we conducted our third and final set of analyses with controls for the effects of Complement Length (i.e. Coda Length).

Our investigation begins with a consideration of the effects of Coda Length on the response time latencies for monoconsonantal heads with varying CSDV's for each Coda Length. Table 3.6 presents the RT latency data for this set of comparisons.

a) CVC

CSDV	RT
10	618.99
9	569.12
8	627.78
7	
6	520.35
5	531.08
4	533.88

b) CVCC

CSDV	RT
10	659.76
9	588.85
8	672.22
7	568.80
6	595.59
5	591.10
4	551.55

c) CVCCC

CSDV	RT
10	
9	672.83
8	
7	634.97
6	574.62
5	563.86
4	642.76

Table 3.6 -

The Effects of Complement Length on Monoconsonantal Heads

Three one-way ANOVA's (i.e. one for each table) revealed that the effect of head CSDV was significant for each syllabic configuration type:

(a) CVC ($F_{5,33}$= 31.55; $p < .001$)

(b) CVCC ($F_{6,33}$= 14.84; $p < .001$)

(c) CVCCC ($F_{4,28}$= 7.33; $p < .001$).

Although the ANOVA revealed significant effects for CSDV, we unable to clearly identify whether or not the data supports our predictions. Hence, this level of analysis has shown that CSDV significantly affects response time latencies, however, it is possible that complement length masks or mitigates the effect of a head's CSDV.

Another interesting observation which can be made based on Table 3.6 concerns the status of stimuli with voiceless stop (CSDV 10) and fricative (CSDV 8) monoconsonantal heads. The RT data in Tables 3.6 a and 3.6b indicate that subjects took longer to produce stimuli with voiceless heads than those with voiced heads. This is surprising given that both the proponents of Preference Theory and Libben would predict that a voiceless-head would be more preferred than a voiced-head.

In general, we find that the RT collected and the conclusions drawn from monoconsonantal heads is less than satisfying. It is possible that when we holding Head Length and CSDV constant that the other factors influence RT latencies (e.g. Coda Length or CSDV).

The inconclusiveness of these results led us to replicate this analyses with diconsonantal heads to see if there would be a balancing effect. A one-way ANOVA based on the RT latencies in Table 3.7 revealed an overall effect for head CSDV for monoconsonantal ($F_{5,29}= 9.70$; $p< .001$) and diconsonantal ($F_{5,34}= 6.95$; $p< .001$), but not for triconsonantal heads ($p= .02$).

Post-hoc analyses of each data set revealed, once again, that the majority of the significant differences identified are related to the exceptional fricative-stop clusters with a CSDV of -2. In general, RT latencies decrease as head CSDV increases. Therefore, the data we collected for diconsonantal heads with different CSDV's tend to support our initial predictions.

a) CCVC

CSDV	RT
6	600.40
5	610.14
4	574.18
3	636.13
2	611.33
-2	677.24

b) CCVCC

CSDV	RT
6	714.08
5	710.05
4	731.40
3	718.20
2	700.41
-2	785.96

c) CCVCCC

CSDV	RT
6	
5	763.48
4	
3	690.90
2	630.71
-2	724.13

Table 3.7 -

The Effects of Complement Length on Diconsonantal Heads

If we compare the findings based on Table 3.6 with those based on Table 3.7, we can conclude that the effects of Coda Length decreases as the Head Length increases. That is to say, as the effect of Complement Length decreases, the effect of CSDV increases. It is important to note that the contributing factors appear to work in a synergistic manner. Consequently, a weighted reformulation of our evaluation metric may be warranted. However, this does not minimize the fact that these factors affect response time latencies in a manner which is consistent with both Vennemann's and Libben's predictions for head configurations.

3.2.2 Coda Evaluations

The second stage of our analysis focuses on the effect of the SV's and CSDV's for a given coda configuration and the Complement Length (i.e. Head a 3. Based on this information we grouped the coda clusters into three levels, high (SV 7-10), mid (SV 4-6) and low (SV 1-3).

Given the contradictory formulation of the Coda Law, we would expect one of two possible outcomes. First, if subsection (b) is correct and a low SV is preferred, then the response time latencies should be the lowest for the low level codas and the longest for the high level codas. However, if subsection (c) and Libben are correct (i.e. a high SV is preferred), then the response time latencies should be the lowest for the high level codas and the longest for the low level codas.

3.2.2.1 The Effects of Slope

Based on these groupings, a one-way ANOVA revealed an overall effect for each of the SV ranges for codas ($F_{2,35}= 49.50$; $p< .001$). A post-hoc Scheffe F-test demonstrated a significant difference for the RT latencies between high and low, and mid and low level heads ($p< .05$), but not between mid and high. The mean response latencies presented in Table 3.8 indicate that subjects responded more quickly to stimuli with high SV's. Hence, we find support for codas which exhibit a sharp Slope towards the preceding nucleus.

Coda Level	RT (ms)
High(SV 7-10)	663.15
Mid (SV 4-6)	674.54
Low (SV 1-3)	740.43

Table 3.8 - The Effects of Slope

These findings in addition to the initial findings concerning the preferred nature of a head with a high SV suggest that an ideal CVC syllable would contain maximally consonantal margins which result in sharp slopes from the syllable margins towards the syllable nucleus. This is counter-intuitive given Hooper's work and the universality of the Optimal Syllable. As with our initial head analysis, these findings suggest that in addition to Length, Slope also affect RT latencies. Thus, our systematic investigation continues with a consideration of the effect CSDV for codas of fixed Lengths on RT's.

3.2.2.2 The Effects of CSDV

Although the first coda analysis clearly suggested that a high SV was preferred, it is possible that these findings were affected by the effects of length because more that half of the codas with high SV are monoconsonantal. Hence, in the second stage of the coda analysis the codas were grouped by Length (i.e. C, CC, or CCC) and then subgrouped by CSDV's. Consequently our data was arranged as follows:

a) monoconsonantal codas with CSDV's from 6 to 10

b) diconsonantal codas with CSDV's from 1 to 6

c) the triconsonantal coda with a CSDV of 6 was not considered.

Based on the RT data presented in Table 3.9 a one-way ANOVA revealed an overall effect for the CSDV of monoconsonantal codas ($F_{6,34}$= 9.57; $p< .001$) and diconsonantal codas ($F_{5,34}$= 19.65; $p< .001$).

Coda Length	CSDV	RT (ms)
C	10	609.92
C	9	577.04
C	8	594.83
C	7	543.00
C	6	601.03
C	5	564.41
C	4	604.84
CC	6	664.34
CC	5	667.80
CC	4	687.58
CC	3	744.35
CC	2	719.84
CC	1	808.36

Table 3.9 - The Effects of CSDV

The RT data obtained for monoconsonantal codas failed to exhibit a clear pattern for the effect of CSDV on RT latencies. However, based on a Fisher PLSD analysis we can conclude that the general trend in the data which suggests an inverse relation between CSDV's and RT's is significant ($p < .05$). Hence, our RT data for diconsonantal codas clearly supports the preferred nature of a high CSDV (i.e. a sharp drop towards the nucleus).

3.2.2.3 Effect of Complement Length

Given the contradictory findings concerning the nature of the preferred monoconsonantal coda configurations in 3.2.2.2, we were led to question the possible effects of Complement Length (i.e. Head Length). When we control for

Complement Length we can selectively investigate the effects of coda CSDV's on processing times. Table 3.10 presents the RT data and syllabic configurations taken into consideration during this analysis.

a) CVC

CSDV	RT
10	609.92
9	577.04
8	594.83
7	543.00
6	575.75
5	512.51
4	597.94

b) CCVC

CSDV	RT
10	677.64
9	643.99
8	656.18
7	661.84
6	622.71
5	633.53
4	690.82

c) CCCVC

CSDV	RT
10	752.97
9	
8	731.17
7	736.55
6	724.55
5	
4	

Table 3.10 -

The Effects of Complement Length on Monoconsonantal Codas

As with the head analyses, three one-way ANOVA's (i.e. one for each table) were conducted. These analyses revealed that the effect of coda CSDV was significant for CVC ($F_{6,34}$= 18.45; $p< .001$) and CCVC syllables ($F_{6,33}$= 9.35; $p< .05$) but not for CCCVC syllables ($p= .762$).

In the case of monoconsonantal codas, the data suggests that, except for CSDV level 4, there is a direct correspondence between RT's and CSDV's. That is to say, the data from Table 3.10a indicates that a coda with a low CSDV is easier to process. A Scheffe F-test revealed that the difference between the RT latencies for each CSDV level were significant ($p< .05$). The data from diconsonantal codas, however, suggests that a coda with a high CSDV is easier to process. In general, the difference between the RT latencies for each CSDV level were not shown to be significant during post-hoc analyses.

The final stage of our analysis considers the data collected based on the CSDV for diconsonantal codas with controlled Complement Lengths. This data is presented in Table 3.11.

a) CVCC

SV	RT
6	613.24
5	627.23
4	611.29
3	594.91
2	625.26
1	617.94

b) CCVCC

SV	RT
6	700.97
5	696.00
4	677.23
3	744.35
2	719.84
1	808.36

c) CCCVCC

SV	RT
6	834.19
5	768.26
4	771.42
3	865.29
2	757.59
1	757.16

Table 3.11 -

The Effects of Complement Length on Diconsonantal Codas

Three one-way ANOVA's revealed that the effect of coda CSDV was significant for CCVCC ($F_{5,34}$= 13.72; $p < .001$) and CCCVCC ($F_{5,30}$= 3.45 $p < .005$) configurations. However, CSDV did not play a significant role in shaping the RT latencies for CVCC ($p = .405$) configurations. If we consider the RT latencies for CVCC configurations, the effect of coda CSDV on the RT latencies is minimal. However, the RT latencies for CCVCC and CCCVCC configurations tend to increase as the CSDV of the coda decreases. Hence, the RT data for CCVCC and CCCVCC configurations indicates that a higher SV is preferable.

3.3 Summary and Conclusions

At the beginning of our analysis, Stimulus, Head and Coda Length were shown to be significant. These finding served to validate our use of RT latencies as an overall measure of processing time. However, it also called into question our assertion that the configuration and composition of subsyllabic units can affect language processing in a manner which is consistent with the claims of Preference Theory.

More specifically, based on our operationalization of Vennemannian Theory, we predicted that heads which exhibit a steep Slope towards the syllable nucleus (i.e. a high Slope Value) and codas which either exhibit an high or low SV's would generate shorter RT latencies. Based on our operationalization of the Preference Laws, we suggest that head and coda configurations which exhibit lower response time latencies are easier to process which we equate with being a more preferred configuration. In addition, Libben suggested the preferred nature of subsyllabic configurations, as characterized by the Preference Laws, should be collapsed into the general statement- The shorter and stronger, the better. Hence, based on Libben we predicted that a high SV for any head or coda configuration would generate low RT's and correspond with the ease of processing we associated with preferred configurations. Given our use of the Slope Value evaluation metric it was possible for us to empirically test these claims.

The Head Evaluations, Section 3.2.1, indicated that the effects of Slope, CSDV, and Complement Length (i.e. Coda Length) could modify RT latencies. Our analysis of Slope revealed that heads with high SV's did indeed correspond with the lowest RT latencies. These findings were further supported by the analyses for diconsonantal heads with varying CSDV's because we found during a post-hoc analysis that significant differences did exist between all level and the exceptional heads with SV's of -2. Also this level of analysis revealed that as Head Length increased so do RT latencies. However, for monoconsonantal heads the results were in the opposite direction to our predictions.

Our final level of analysis was one in which we considered the effects of Complement Length (i.e. Coda Length) on the RT latencies generated by mono- and diconsonantal heads with varying CSDV's. Our analyses revealed that despite a statistical significance, RT's for configurations with monoconsonantal heads failed to exhibit a clear relation with the corresponding CSDV's. In the case of the analyses of RT latencies for configurations with diconsonantal heads we were able to determine that as CSDV's increased, RT's decreased. These findings support the predictions which say that heads which exhibit a steep Slope towards the nucleus are easier to process.

In general, the effects of CSDV and Complement Length did not affect the direction of the correspondence between RT latencies and Slope. Rather, if a factor was not controlled for, it tended to moderate or mask the effect of other factors. Therefore, our head analyses have, as Vennemann and Libben predicted, shown that as Slope Values increase, RT latencies decrease. Hence our findings the claims that heads with higher Slope Values are easier to process.

The findings from our Coda Evaluations in Section 3.2.1.4 were less concise. When we considered the relation between SV's and RT's, Section 3.2.2, we found that the higher the Slope Value, the lower the response time latencies. This indicated that a steep slope from the syllable margin towards the syllable nucleus was easier to process. In addition, the results from the CSDV analysis for diconsonantal codas also supports the preferred nature of a steep slope towards the nucleus. However, the results for monoconsonantal codas suggested the opposite.

In the final level of analysis, where we considered the effect of Complement Length, the results revealed that for monoconsonantal codas Complement Length contributes to the overall processing time. Hence, the RT data for these configurations was moderated by the effects of Complement Length. In the case of diconsonantal codas, CSDV was shown to affect the RT latencies associated when the Complement Length was one or two. This data revealed that higher CSDV's corresponded, in general, with lower RT latencies. Hence, as with the majority of the data analyzed during the coda evaluation, a coda which exhibits a steep drop in Slope (i.e. a high SV's) are processed more quickly. Therefore, we suggest that coda which exhibits higher SV's are more preferred.

In summary, we have seen that the Slope, CSDV, and the Length of a given configuration as well as Complement Length all contribute to the shaping of RT latencies in a synergistic manner. Based on our operationalization of the Preference Laws and the preceding analysis three important facts emerge. First, our RT analyses have revealed, more clearly than Li's did, that the principles and parameters of Preference affect language processing. We found that the RT data primarily supported the ease of processing associated with heads and codas with high Slope Values (i.e. steep Slopes towards the syllable nucleus).

However, due to the small amount of support for the preferred nature of codas with low SV's and the fact that we did not consider the affects of vowel in our development of the stimuli we were not able to prove a disassociation between the predictions based on the operationalization of of Vennemannian theory and Libben's suggestion that the Preference Laws should be collapsed into one statement (the higher the SV the more preferred the configuration).

Second, our data analyses also indicate that the synergistic effect of Complement Length, which is beyond the scope of the Head and Coda Laws, our evaluation metric and our statistical measures, affects response time latencies. Consequently, we suggest that a reformulation of our evaluation metric may be warranted. The reformulation of the metric should include a means of weighting the effect of Length (i.e. $\underline{\Delta}$), as well as factoring in the effects of overall Length of syllable (i.e. including Complement Length). A reformulation of our evaluation metric might yield clearer results concerning the role of syllabic configurations and Preference in language processing.

The final and most important fact which emerges from our empirical study is the fact that we have been able empirically substantiated the effect of the principles an parameters of Preference Theory in language processing within the phonotactic constraints of English. However, in addition to the language specific claims, Vennemann also suggests that Preference Theory is a universal phenomena. Due to the limitation imposed by English phonotactics, we have not been able to address the issue of universality. This claim, however, forms the basis of our second experiment in which the phonotactic constraints of English are lifted. The results obtained here should be considered to be a base-line for further investigations. That is to say, since we have validated the claims of Preference Theory within this domain, the observations and methodology should be transferable to other domains (e.g. other languages, universal investigations, language acquisition studies, etc...). The experiment reported on in Chapter 4 represents the first psycholinguistic investigation into the universal nature of Preference Theory in language processing.

Chapter 4

The Preference Laws Beyond Phonotactic Constraints

This chapter reports on the first psycholinguistic investigation into the universal nature of the Preference Laws for Syllable Structure and their role in language processing. In other words, this experiment investigates whether or not the Preference Laws will predict the relative difficulty experienced by English speakers who are asked to produce a range of consonant clusters which are no longer constrained by English phonotactics. Vennemann (1988: 4) suggests that Preference Theory is rooted in our phonetic endowment and that the claims of Preference Theory are universal. Therefore, the use of non-English stimuli should yield results which are comprable with the results based on the English-like stimuli employed in our first experiment.

The design of this experiment is based upon the calculus-based evaluation metric developed in Chapter 2 and the experimental methodology developed in Chapter 3. However, the stimuli which we have employed in this study are not constrained by the phonotactics of English. Therefore, in this experiment, it is possible for us to address the question: "Can the claims of the Preference Laws for Syllable Structure be shown to be language universals which affect language processing?"

As we saw in Chapter 3, the effects of Slope, CSDV, and Length for a given configuration and Complement Length on response latencies can be taken as indicators of the relative ease of processing for a given configuration. Therefore, if Slope, CSDV, and Length for a given configuration can be shown to affect RT latencies, then an analysis of the effects can identify whether or not the preference relations embodied in the Preference Laws function at a universal level. If, however, the effects of Slope, CSDV, and Length for a given configuration do not conform to the predictions based on our operationalization of the Preference Laws, then it is possible that the effects found in the first experiment represent a language specific phenomena.

4.1 Experimental Design

4.1.1 Subjects (n=17)

The subjects in this experiment were 8 males and 9 females with an average age of 24.9 years recruited from the students of the University of Calgary and the staff members of the Ajax-Pickering Hospital. As with the first experiment, all subjects:

(a) possessed normal or corrected to normal vision;

(b) were right handed;

(c) demonstrated an adequate oral reading ability, and

(d) were monolingual speakers of English.

4.1.2 Stimuli

In this case our combinations were not restricted by English phonotactics. Therefore, we selected random elements systematically from the various preference value levels. Heads and codas were randomly combined to form each stimulus. A number of mono- and triconsonantal clusters were included, but our primary focus was on diconsonantal heads and codas.

Based on the selection process depicted in Figure 3.4, we randomly combined unrestricted cluster types to form the stimulus list in Table 4.1.

PT0.	flamp	28.	drisg	66.	dfikm	104.	kizt
PT1.	ript	29.	mavf	67.	kinz	105.	fnalk
PT2.	lnad	30.	vgim	68.	tigm	106.	msat
PT3.	ftin	31.	mzasn	69.	gnimnt	107.	lamr
PT4.	bagv	32.	basl	70.	falp	108.	mnak
PT5.	vtiv	33.	rlist	71.	zivk	109.	nfalr
PT6.	basp	34.	vbad	72.	tatr	110.	msants
PT7.	mizg	35.	rsavn	73.	sirn	111.	rmam
PT8.	targ	36.	vrazb	74.	filv	112.	fabs
PT9.	tnam	37.	mazg	75.	dnapts	113.	pafm
		38.	nlat	76.	ltamp	114.	tsaf
1.	ftants	39.	stifpg	77.	zilg	115.	dkink
2.	ratsm	40.	lvavl	78.	talpk	116.	galn
3.	mbisr	41.	fizn	79.	fbadst	117.	fvits
4.	gidg	42.	pimt	80.	lfarg	118.	tim
5.	mnad	43.	zadv	81.	gsirt	119.	bisf
6.	rpadr	44.	tampt	82.	dilp	120.	dzat
7.	tprik	45.	namg	83.	talpn	121.	fidn
8.	nid	46.	zind	84.	vald	122.	sprasf
9.	ltfil	47.	vazp	85.	gzatz	123.	slaf
10.	rlat	48.	bakl	86.	pilf	124.	dpant
11.	mikg	49.	falv	87.	kzad	125.	nirt
12.	lnirl	50.	kamz	88.	lmavz	126.	bgiz
13.	parg	51.	gamn	89.	rnan	127.	tmiz
14.	snald	52.	favt	90.	kmit	128.	tabd
15.	ltrim	53.	mazl	91.	ksid	129.	fnam
16.	plafv	54.	simt	92.	bpaf	130.	talbt
17.	sgipr	55.	fsanf	93.	ilm	131.	zfasn
18.	vzibk	56.	bmag	94.	bzists		
19.	kragv	57.	fimz	95.	npalz		
20.	tpritk	58.	tnar	96.	kzap		
21.	rvazv	59.	lkit	97.	ftalm		
22.	fism	60.	zlalg	98.	bsat		
23.	misk	61.	kavb	99.	dvitm		
24.	znazk	62.	gpags	100.	gkinl		
25.	glavl	63.	ktim	101.	nmak		
26.	srasd	64.	mirf	102.	gdar		
27.	risv	65.	garv	103.	vivm		

TABLE 4.1 - STIMULUS LIST #2

The overall frequencies of occurrence for head and coda types are represented in Tables 4.2a to 4.2e, based on the stimuli set represented in Table 4.1.

(a) single C's

	H	C
p	5	1
t	6	10
k	4	2
b	5	0
d	1	6
g	3	2
f	9	3
s	2	0
v	3	1
z	4	2
m	8	6
n	3	2
l	1	1
r	3	2

(b) CCC heads

tpr	2
lft	1
ltr	1
spr	1

(c) CCC codas

tsm	1
pts	1
lpn	1
fpg	1
mpt	1
mnt	1
sts	1
lpk	1
dst	1
lbd	1
nts	2

(d) CC heads

right

left

	p	t	k	b	d	g	f	s	v	z	m	n	l	r
p													1	
t		1							1			2		
k		1						1		2	1			
b	1					1		1		1	1			
d	1		1				1		1	1		1		1
g	2				1			1		1		1	1	
f	3		1					1	1			2	1	
s		1					1					1	1	1
v		1		1		1							1	1
z							1					1	1	
m				1				2		1		2		
n	1						1				1		1	
l		1	1				1		1		1	2		
r	1							1	1		1	1	2	

(e) CC codas

right

left	p	t	k	b	d	g	f	s	v	z	m	n	l	r
p		1												1
t								1		1	1			1
k						1					1		1	
b			1		1			1						
d						1			1			1		1
g								1	2		1			
f									1		1			
s	1	1	1		1	1	2		1		1	2	1	1
v		1	1	1			1			1	1	1	1	
z	1	1	1	1		2			1			1	1	
m	1	2				1				2		1		1
n		1	1	1		1				1			1	
l	2		1		2	2	1		2	1	2	1		1
r		2				3	1		1			1	1	

Table 4.2 -

The Frequency of Distribution of Segments in List #2

If we compare the range of stimuli employed in this study with the acceptable range for English (recall Figures 3.5 and 3.6), we can see that English employs a very small subset of the total configurations possible given our grapheme-pool.

4.1.3 Procedure & Apparatus

The procedure for this experiment was identical to the procedure for Experiment 1, which is detailed in Section 3.2.3.

4.2 Analysis of Response Time Latencies

As we saw in Section 3.2, it is necessary to validate our use of response time latencies as a measure of processing time. In order to ensure that the RT latencies obtained reflected processing time rather than individual variations in response methods (i.e. false starts or response internal hesitations) we employed three one-way ANOVA's which assessed the overall effect of the Length of the Stimulus, Head and Coda on RT latencies. The analyses revealed a significant effect for Stimulus Length ($F_{3,15}= 25.50$; $p< .001$), Head Length ($F_{2,14}= 32.68$; $p< .001$) and Coda Length ($F_{2,15}= 13.70$; $p< .001$). Thus, once again, we found that subjects were processing the stimuli before they were responding. Hence, we could rely upon the RT data as a fine measure of language processing.

However, as in Chapter 3, the fact that the RT latencies were significantly affected by Head and Coda Length brings into question the universal claims of Preference Theory. In order to systematically investigate the effects of Preference beyond the phonotactic constraints of English we employed a similar three stage analysis of the effects of Slope, CSDV and Complement Length on language processing. This three stage approach allows us to hold an increasing number of the contributing factors constant while investigating the effects on RT's. In the following sections we will consider each of these formats for heads and codas respectively.

4.2.1 Head Evaluations

Given that we have lifted the constraints of English phonotactics, the Slope Values for heads now range from -6 to 10. Within this range monoconsonantal heads continue to range from 4 to 10, but diconsonantal heads now range from -6 to 6 and triconsonantal heads are limited to a SV of -0.5, 2, 2.5 or 3.

4.2.1.1 The Effects of Slope

For the purposes of our initial investigation of the effect of SV on response time latencies we subgrouped the positive and negative SV ranges and isolated those clusters which evaluated as zero. This resulted in the six SV ranges in Table 4.3.

SV Level	RT (ms)
-6 to -4	946.00
-3 to -1	868.94
0	892.23
1 to 3	851.91
4 to 6	786.17
7 to 10	721.96

Table 4.3 - The Effects of Slope

Given our operationalization of the Head Law, we expected that response time latencies should be the lowest for the high level heads and the longest for the low level heads. The results obtained from a one-way ANOVA confirmed the overall effect of SV for each of the ranges ($F_{5,15} = 11.91$; $p < .001$). A second ANOVA revealed significant differences between the RT's generated in response to positive and negative SV's, 819.04 and 907.72 milliseconds, respectively ($F_{1,15} = 17.41$; $p < .001$). Based on the data we can see that high level heads do correspond, as predicted, with the shortest response latencies.

It is interesting to note that despite fact the results from this analysis show that subjects took longer to respond to the non-English stimuli they are still responding to the Slope of the configurations. In fact, the RT data in Table 4.3, exemplify the predictions in (23) and (24) more clearly than the RT data obtained from the constrained stimuli in Chapter 3. Given the sparsity of representation which results from the phonotactic constraints of English it is possible that the variability of the analysis in Section 3.2.1.1 reflects a frequency effect stemming from native speaker familiarity with the clusters tested. It is also possible that the clarity of the effect of SV on the RT's from the unconstrained data reflects a larger sample or a more heterogeneous sample (i.e. statistically more viable). Therefore, we anticipated that the insights which can be obtained from the RT data associated with the unconstrained stimuli in this experiment will more accurately represent the effects of Preference Theory in language processing because another factor, that of native speaker intuitions, was controlled by the random nature of the stimuli employed in this study. With this expectation in mind we replicated the analyses conducted in Chapter 3 in order to gain a clearer understanding of the principles and parameters of Preference Theory and language universals.

4.2.1.2 The Effects of CSDV

Our systematic exploration of the overall effects of more or less preferred head configurations continues with the investigation of the effect CSDV's have on heads of fixed Lengths on RT latencies. In this analysis Head Length was held constant. Hence, heads were first grouped by Length (i.e. C, CC, or CCC)

Length (i.e. C, CC, or CCC) and then subgrouped by CSDV. Table 4.4a represents the RT data for monoconsonantal heads and Table 4.4b and 4.4c represent the data for di- and triconsonantal heads, respectively.

a) monoconsonantal

Head Length	CSDV	RT (ms)
C	10	743.44
C	9	700.33
C	8	739.40
C	7	682.23
C	6	608.60
C	5	713.87
C	4	709.87

b) diconsonantal

Head Length	CSDV	RT (ms)
CC	6	796.27
CC	5	807.33
CC	4	774.49
CC	3	870.49
CC	2	798.80
CC	1	827.20
CC	0	885.27
CC	-1	865.71
CC	-2	860.09
CC	-3	831.96
CC	-4	933.07
CC	-5	911.73
CC	-6	968.00

c) triconsonantal

Head Length	CSDV	RT (ms)
CCC	6	891.08
CCC	4	923.39
CCC	1	818.46
CCC	0	844.62

Table 4.4 - The Effects of CSDV

Our one-way analyses of variance identified a significant effect of CSDV for monoconsonantal heads ($F_{6,14}$= 4.33; p< .001), but not for diconsonantal heads (p=.003) or triconsonantal heads (p= .434). Furthermore, post-hoc analyses using a Fisher PLSD failed to identify any significant differences for the CSDV levels of di- and triconsonantal heads. In general, the RT data for monoconsonantal heads indicated that high SV's are preferred. However, a post-hoc analysis failed to suggest a pattern for the significant differences amongst the response time latencies for CSDV levels. This suggests that Preference Theory may still be at work, but that the effects of the CSDV's for heads may be masked by the effects of Head Length, Complement Length or the novelty of the stimuli. The lack of significant results for di- and triconsonantal heads suggests that the additional factors which shape syllabic configurations may be the underlying cause.

Consequently, we reanalyzed our di- and triconsonantal heads results using more general groupings for CSDV levels. For diconsonantal heads a significant effect for the negative range of CSDV's in comparison with those values greater than zero (0) was identified during a post-hoc Scheffe F-test in which diconsonantal clusters were ranked as negative CSDV, zero, or positive CSDV ($p < .05$). However, the re-analysis of the triconsonantal heads failed to revealed any significant differences ($p = .249$). This is not surprising given the limited range, extremely unusual nature of the stimuli and lack of responses in a third of the cases. Consequently, based on the positive results from the initial analysis of monoconsonantal heads and the re-analysis of the diconsonantal heads we decided to limit our final investigations of head clusters to mono- and diconsonantal head configurations.

4.2.1.3 The Effects of Complement Length

These analyses systematically investigate the effects of CSDV and Complement Length (i.e. Coda Length) on RT latencies for mono- and diconsonantal heads. Table 4.5 presents the response time latencies for monoconsonantal heads paired with diconsonantal codas. We limited our investigations to the CVCC configuration because the CVC and CVCCC configurations were sparsely represented in the data, hence they were of questionable statistical validity.

CSDV	RT
10	761.59
9	686.11
8	725.32
7	660.08
6	635.66
5	703.43
4	608.57

Table 4.5 -
The Effects of Complement Length on Monoconsonantal Heads

A one-way analysis of variance for the CVCC syllabic configurations revealed a significant effect for CSDV ($F_{6,13} = 5.86$; $p < .001$). It is interesting to note that the heads with a CSDV of 10 and 8 correspond with the highest RT latencies. A post-hoc Fisher PLSD analysis revealed that the difference between the heads with CSDV's of 10 and 8 and all other CSDV levels tended to be significant ($p < .05$). This is surprising given that the RT latencies for the heads with CSDV's of 10 and 8 should be lower than the RT's for the heads with CSDV's of 9 and 7, respectively, because the heads with CSDV's of 10 and 8 generate a steeper Slope than do their voiceless counterparts (i.e. the heads with CSDV's of 9 and 7).

The fact that this effect occurred in our first experiment, as well, suggests that there may be a systematic effect. It is possible that the higher RT latencies reflect a lag in voice-onset time which means that the voice-cue may not have been activated exactly at the beginning of the response by the voiceless heads. Also, we would suggest that the magnitude of this effect in this experiment may be the result of a "surprise effect". That is to say, since subjects were expecting complicated and unusual stimuli, the occurrence of simple and familiar may have taken them by surprise.

However, this data cannot not suggest whether or not the RT latencies were affected by Complement Length. Hence, the next stage of our investigation took into consideration of the effect of a wider range of syllabic configurations and CSDV's during the analysis of diconsonantal heads with either a mono- or diconsonantal complement. The RT latencies obtained are pictured in Tables 4.6 a & b.

a) CCVC

CSDV	RT
6	
5	
4	729.19
3	694.67
2	768.86
1	703.43
0	772.05
-1	726.57
-2	741.77
-3	713.43
-4	
-5	
-6	

b) CCVCC

CSDV	RT
6	793.46
5	792.00
4	831.46
3	977.09
2	787.61
1	956.85
0	976.00
-1	942.82
-2	850.24
-3	884.42
-4	930.18
-5	860.00
-6	974.55

Table 4.6 -
The Effects of Complement Length on Diconsonantal Heads

The one-way ANOVA for the response time data for CCVC configurations indicates that the effect of CSDV was marginally significant ($F_{7,13} = 2.16$; $p<$

.04). Unfortunately, we were unable to identify a clear pattern for the effect. This can be attributed to the small range of representation and the fact that the extreme CSDV levels were not represented.

However, the results from the one-way ANOVA for the response time data for CCVCC configurations indicates that the effect of CSDV was significant ($F_{12,13}$= 2.16; $p< .003$). The data in Table 4.6b indicates that the duration of RT latency increase as the CSDV decreases. Furthermore, it can be said that RT latencies increase as the stimuli become less English-like (i.e. CSDV's ranging from 2 to 6 and -2).

4.2.2 Coda Evaluations

With the removal of the phonotactic constraints of English, the Slope Values for codas now range from -6 to 10. Within this range monoconsonantal heads continue to range from 4 to 10, but diconsonantal codas now range from -6 to 6 and triconsonantal codas are limited to a SV of -0.5, 2, 2.5 or 3.

4.2.2.1 The Effects of Slope

For the purposes of our initial investigation of the effect of SV on response time latencies we subgrouped the positive and negative ranges and isolated those clusters which evaluated as zero (0). This resulted in the six SV ranges depicted in Table 4.7.

SV Level	RT (ms)
-6 to -4	877.82
-3 to -1	822.49
0	875.96
1 to 3	842.04
4 to 6	775.24
7 to 10	787.85

Table 4.7 - The Effects of Slope

Once again, the use of non-English stimuli has succeeded in clearly identifying the effects of Slope in a manner which is consistent with our predictions in (23) and (24) based on our operationalization of the Preference Laws and Libben's assertions. Our analysis of the RT latencies for the six groups revealed a significant effect for Slope Value ($F_{6,15} = 3.30$; $p < .005$). Two observations can be made based on the RT latencies in Table 4.7. First, the fact that the zero SV group yielded the longest RT latency suggests that some Slope, even if it is a negative Slope is better than no Slope at all. Second, the data indicates that codas with a high SV are processed more quickly. Hence, as would be predicted, a steep Slope towards the syllable nucleus is preferred.

4.2.2.2 The Effects of CSDV

In this analysis we investigated the effect of CSDV's for fixed-length codas on RT latencies. Coda configurations were first grouped by Length (i.e. C, CC, or CCC) and then subgrouped by CSDV. Tables 4.8a to 4.8c represent the RT data for mono, di- and triconsonantal codas, respectively.

a) monoconsonantal

Head Length	CSDV	RT (ms)
C	10	851.09
C	9	658.16
C	8	858.95
C	7	784.00
C	6	776.13
C	5	880.86
C	4	741.43

b) diconsonantal

Head Length	CSDV	RT (ms)
CC	6	740.93
CC	5	728.84
CC	4	754.81
CC	3	771.24
CC	2	821.77
CC	1	791.97
CC	0	882.89
CC	-1	876.62
CC	-2	801.82
CC	-3	773.33
CC	-4	955.38
CC	-5	825.20
CC	-6	967.33

c) triconsonantal

Head Length	CSDV	RT (ms)
CCC	5	772.27
CCC	4	773.47
CCC	2	906.40
CCC	1	920.31
CCC	-2	812.53
CCC	-4	763.20

Table 4.8 - The Effects of CSDV

Three one-way ANOVA's were conducted in order to assess the effects of CSDV. The monoconsonantal coda analysis revealed that CSDV significantly affects RT latencies in a manner which is consistent with the predictions that a steep Slope towards the nucleus is preferred ($F_{6,13}$= 5.06; p<. 001). Similarly, the diconsonantal coda analysis revealed a significant effect for CSDV which also supports the preferred nature of a coda with a high SV ($F_{12,14}$= 7.33; p< .001).

However, the triconsonantal analysis of variance failed to identify a significant effect ($p= .01$). The lack of significance is not surprising given the limited range of CSDV's. A post-hoc Fisher PLSD did, however, reveal a significant difference between codas with CSDV's of 1 and 2, and the other levels ($p< .05$). The codas with CSDV's of 1 and 2 exhibited the greatest RT latencies.

It is interesting to note that the voiceless monoconsonantal codas (i.e. CSDV 8 and 10) in Table 4.8a exhibited the greatest RT latencies for monoconsonantal codas. This does not refute or call into question the predictions based on our operationalization of the Coda Law because the higher RT latencies for these codas conform to subsection (b) which states that a weak coda is preferred (i.e. a coda with a lower SV or CSDV). However, these findings do call into question Libben's predictions. Yet if we consider the data from the diconsonantal analyses, we can see that this data suggests that a a coda with a steep Slope towards the syllable nucleus is indeed easier to process. The lack of uniformity in the results, suggest that we should consider the effects of Complement Length.

4.2.2.3 The Effects of Complement Length

This final set of analyses systematically investigates the effects of CSDV and Complement Length on RT latencies for mono- and diconsonantal codas. We limited our investigations to CVCC and CCVCC configurations because the other configurations were sparsely represented in the data, thus they were of questionable statistical validity. Table 4.9 presents the RT latencies obtained.

a) CVCC

CSDV	RT
6	546.00
5	633.05
4	627.12
3	678.84
2	683.27
1	674.33
0	724.96
-1	687.43
-2	753.44
-3	729.62
-4	
-5	614.29
-6	828.00

b) CCVCC

CSDV	RT
6	902.67
5	803.17
4	834.58
3	813.33
2	935.58
1	850.00
0	997.67
-1	1038.78
-2	833.96
-3	
-4	980.00
-5	1008.00
-6	1045.67

Table 4.9 -
The Effects of Complement Length on Diconsonantal Codas

Two one-way analyses of variance revealed an overall effect for CSDV for CVCC ($F_{11,13}$= 10.08; $p< .001$) and CCVCC configurations ($F_{11,11}$; $p< .002$). The response time latencies in these tables clearly indicate that codas with higher CSDV's are preferred. In approximately half of the cases a Fisher PLSD post-hoc analysis revealed a significant difference between CSDV levels and their effects on RT latencies ($p< .05$). Consequently, we can conclude that Complement Length contributes to the overall processing time required because when we control for Complement Length the effects of Slope are more clearly revealed.

4.3 Summary and Conclusions

The key point which emerges from the analysis of the response time latency data from this experiment is that the use of non-English stimuli has, in general, yielded support for our predictions in (23) and (24). In fact, in some cases our use of non-English stimuli has revealed these effects more effectively than in our first experiment (i.e. the effect of SV's and CSDV's). This finding suggests two things. First, that Preference Theory truly is a language universal. And second that by controlling for native speaker intuitions or knowledge concerning the language specific phonotactic restrictions we can investigate the interactive and synergistic effects of SV, CSDV and Complement Length more readily.

On a more specific level, the Head Evaluations in Section 4.2.1 revealed that, as was predicted, heads with higher SV's were easier to produce. However, the results from the CSDV analyses tended to be more difficult to interpret because monoconsonantal heads were the only configurations which yielded significant results. Unfortunately, we were unable to identify clearly a relation between RT latencies and CSDV's.

The results from our final level of analysis, which considered Complement Length, indicated that for diconsonantal heads the effects of CSDV's could be more clearly identified when Complement Length was held constant. The data revealed that RT latencies increase as CSDV's decrease. Hence, this analysis, like the others, indicate that a head is easier to produce when it exhibits a steep Slope towards the syllable nucleus.

In summary, mono- and diconsonantal heads appear to be the better indicators of the effects of CSDV and complement length. Furthermore, the associated configurations generate effects which parallel the effects found in the first experiment. Hence, the results based on non-English heads can be said to support the universal preference for heads which exhibit a steep Slope towards the syllable nucleus. Therefore, we can conclude that the greater the Slope of a head, the more preferred a head is.

In addition, the findings based on our Coda Evaluations in Section 4.2.2 suggest that the use of non-English stimuli also facilitated our identification of the effects of Slope, CSDV's and Complement Length on the RT latencies generated in response to coda configurations. The SV analysis clearly revealed that codas with high SV's were easier to produce. This findings was replicated in our CSDV analysis for mono- and diconsonantal codas. The fact that the triconsonantal codas failed to reveal an effect for CSDV was attributed to the sparse representation of these configurations in the data. In our final analysis, we saw that when Complement Length was controlled for we were able to assess the effects of CSDV's on RT latencies more effectively.

In general, our investigation revealed that a coda is easier to process the greater the Slope towards the syllable nucleus. Hence, our findings can be taken in support of subsections (a) and (c) of the Coda Law, as well as, Libben's assertion that the greater the SV, the more preferred.

The positive findings which have resulted from this experiment suggest that the use of non-English stimuli and response time latencies is a viable means of investigating the universal nature of the Preference Laws for Syllable Structure and their role in language processing. In conclusion, we suggest that the Preference Laws for Terminal Constituents govern language processing on a universal level, as well as, on a language specific one.

Chapter 5

Concluding Remarks

As we saw in Chapters 1 and 2, since the re-introduction of the syllable as a viable domain in phonological theory, phonologists and psycholinguists have investigated the structure, nature and role of syllabic and subsyllabic units in language. In contrast to the limitations of linear and binarily based phonology, Vennemann and Murray have shown that a gradient view of phonological processes and structures can account for many of the diachronic changes affecting phonology. The gradient nature of phonological change was formalized in The Preference Laws for Syllable Structure, where the Preference Laws specify the domain specific phonological characteristics which identify the preferred nature of subsyllabic configurations.

Preference Theory suggests that less preferred structures should be more susceptible to change. Li interpreted this to mean that less preferred structures should be more difficult to produce. In her study she was able to identify significant differences in accuracy rates which corresponded to the more or less preferred nature of the diconsonantal clusters employed in her study. However, the breadth and depth of her findings were limited by the descriptive nature of her evaluation method and the small range of stimuli.

The psycholinguistic investigations into the role of Preference Theory on language processing detailed in this thesis, however, are able to move beyond Li's limitations through the use of a calculus-based operationalization of the Preference Laws. The operationalization of the Preference Laws is based upon the notion of Slope which characterizes the rate and direction of change in the Consonantal Strengths associated with a head or coda configuration. As a result of the notion of Slope and the evaluation metric we are able to assign a

Slope Value any head or coda configuration. This has enabled us to consider and compare a more diverse range of head and coda configurations.

However, as we have seen, there are a number of differences between the operationalization of the Preference Laws and the interpretation of the Laws by proponents of Preference Theory (cf. Murray 1990). The main differences stem from the fact that the evaluation metric allows us to characterize the more or less preferred nature of a configuration based upon the interactive effect of the Length and composition of the configuration. Proponents of Preference Theory feel that this collapsation is not an accurate interpretation of the Laws, nor does it result in the same predictions. This is true in less than 5% of the cases. More specifically, we found that our evaluation metric made different predictions than the Preference Laws, only in the case of polyconsonantal head configurations which exhibit a Slope actually changes directions.

However, as we saw, in our head and coda analyses (Sections 3.2.1 and 4.2.1; 3.2.2 and 4.2.2) heads and codas which exhibit a steep Slope dropping towards the syllable nucleus, also tend to exhibit shorter response latencies. As Li has shown shorter response latencies are indicative of the ease of processing associated with preferred syllabic configurations. Thus, our findings based on our operationalization metric substantiate the claims of of the Head Law and subsection (c) of the Coda Law, as well as, Libben's hypothesis that higher Slope Values represent subsyllabic units which are preferable.

More importantly, when we considered our findings carefully, we found that a significant interactional effect exists amongst the parameters defined in our operationalization. In particular, when we considered the effects of CSDV's and Complement Length we found that there was an interactive effect which is beyond both the formulation of our evaluation metric and the Preference Laws. In part, the interactions observed can be attributed to the fact that RT is a measure of overall processing time. Therefore, given that all of our stimuli contained heads and codas it is difficult to isolate the domain specific effects from the domain external influences. In order to compensate or control for the interactive effects we would suggest two improvements to our study. First, we would suggest that in addition to the stimuli we selected, it would be fruitful to consider C_1^3V and VC_1^3 type syllables which would be unaffected by complement content and configuration.

Second, it is possible that a weighted reformulation of the evaluation metric would be a more accurate characterization of the relative effects of the individual factors defined by the Preference Laws. Recently, Libben (1990) has suggested that the evaluation metric should be reformulated as $100 - (SV - L^2)$. This reformulation ensures that a geometric relationship exists between head and coda configurations of varying Lengths.

In addition to our study, we suggest that a parallel qualitative study is needed to investigate the degree and direction of phonological changes presented in our quantitative analysis. Conducting a qualitative study would allow us to investigate the errors produced during the administration of our experiments. An accuracy analysis would allow us to consider the the frequency of errors associated with different syllabic configurations, while an error analysis would let us consider the frequency and direction of change associated with different syllabic configurations. More importantly, a qualitative analysis would allow us to consider the local effect of Slope, CSDV's, and complement length. The qualitative findings could then be compared with the quantitative findings of our study in order to gain a better understanding of phonological phenomena which are characterized by the Preference Laws and the true nature of syllable preferences.

In conclusion, we suggest that the nature of the synergistic and mitigating influences we found are indicative of the nature of syllabic phonology and language processing in general. That is to say, despite the fact that an experimental setting is artificial, the findings and observations obtained from this experiment can shed light onto the psycholinguistic "reality" of Preference in language processing. Moreover, psycholinguistic studies can play an important part in the investigation of the role of the Preference Laws in language processing by providing us with an environment in which we can study the nature of Preference over a range of controlled effects and selective targets.

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