From lexical to syllabic organization: Favored and disfavored co-occurrences

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ABSTRACT

This paper deals with the organization of the syllable in natural languages. As a first attempt to understand selection and restriction constraints in syllable structure, we analyzed 14 languages. First, we present some implicational laws connected to the frequencies of syllable types and based on the complexity of onset and coda. Then we tested the relations between segments that appear in the same syllable, or in onset of two consecutive syllables. If we hypothesize that the most frequent syllable types are the most functional ones, searching for a syllabic "architecture" based on C-V co-occurrences may help us explain syllable-structure frames.

1. INTRODUCTION

The question of the natural syllabic unit has remained unresolved at all linguistic levels. Recent studies in neurophysiology considered that the syllable was a central unit in language emergence, acquisition and functioning [11]. Some phonological theories [2] have used the syllabic concept to explain rhythm mechanisms. In the Frame/Content theory [10], the syllable was considered as the universal generator of rhythm. According to this theory, the mandibular cycle underlying the speech frame may have been borrowed from the mandibular cycle originally evolved for mammalian ingestive functions. The open-close alternation was the dimension mostly used by languages for production of consonantal and vocalic "Content" elements. So, the Frame/Content theory shed light on the predominant role of mandibular oscillations in babbling, as in the syllabic structure of natural language lexicons.

Analysis of data for varied languages could help define the concept of the syllable. We could try to understand syllabic organization by studying syllabic structure taxonomies and giving prominence to universal trends for possible combinations. However, syllabic typologies would not be sufficient to establish the phonological concept of the syllable. Typologies permit the suggestion of hypotheses, but they cannot verify them. We assumed that sound patterns that are widely attested among languages might be explained in terms of human capacities in perception, production or both ("substance-based" linguistic, [3], [4], [5].

In this paper, we do not analyze the syllable's linguistic status, but the phonetic elements of which it is composed. We present a search and analysis of favored structures in languages, of the relationship between phonetic units in the same syllable or in two consecutive syllables. We compare syllabic structure trends to ontogenetic data. These results provide some elements for an account of the possible syllabic linguistic unit and permit us to better understand the rule of syllabic frame in the lexical organization of languages.

This study was conducted on using the ULSID (UCLA Lexical and Syllabic Inventory Database), provided by Ian Maddieson [12]. This database was created incorporate genetic and geographical diversity. The data was provided as a lexicon or dictionary cut in syllables. The data for 14 languages was transformed into IPA notation [6]. We have added a fifteenth language, Swedish. Our corpus is currently composed of more than 186 000 syllables, about 70 000 lexicon items.

2. IMPLICATIONAL LAWS

First, we turned syllables into C (consonant) and V (vowel) constituents and we grouped the same structures. We observed that the total number of syllables types was very small as compared to the number of syllables: the 186 252 ULSID's syllables are distributed among twenty-one syllabic structure types only.

We could see that these twenty-one types were not all too frequent. Both main types, CV and CVC, represented together more than eighty-four percents of syllabic structures. By grouping together the syllable structures according to presence or absence of onset and coda, we noted that structures with no onset (VC) were disfavored. In contrast, structures with no coda (CV) were frequent. So a difference between onset and coda in the syllable structures was strongly apparent. Consonant clusters represent only four percent of structures in the database.

We gave prominence to implicational laws connected to presence and frequencies of syllables types and based on the complexity of onset and coda. They confirmed those of Blevins [7]. Indeed, in our sample, if clusters of n consonants are possible in initial position, then clusters of n-i consonants appear in the onset of the syllable system (with i increases 1 to n-1). We had the following implications:

$$CCCV \Rightarrow CCV \Rightarrow CV$$
$$CCCVC \Rightarrow CCVC \Rightarrow CVC$$

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We could observe the same law for the complex codas:

$$CVCCCC \Rightarrow CVCCC \Rightarrow CVCC \Rightarrow CVC$$
$$VCCC \Rightarrow VCC \Rightarrow VC \Rightarrow V$$

We also saw that there was a relationship between frequency of syllable structures and their complexity: the more the syllabic structures complexity increase, the more their frequency decreases.

$$CCCV <<< CCV << CV$$
$$CCCVC <<< CCVC << CVC$$
$$CVCCCC <<< CVCCC << CVCC < CVC$$
$$VCCC <<< VCC << VC < V$$

There were relationships between the complex syllabic structures and we wanted to know if they were also good if we observed segments. The implicational laws were conserved as in these examples:

in Finnish

/spr/ $\Rightarrow$ /sp/ and /str/ $\Rightarrow$ /st/

/spr/ << /sp/ and /str/ << /st/

in Kwakw'ala

/lxs/ $\Rightarrow$ /lx/ and /?xst/ $\Rightarrow$ /?xs/ $\Rightarrow$ /xs/

lxs/ << /lx/ and /?xst/ << /?xs/ < /xs/

in Kannada

/int/ $\Rightarrow$ /in/ $\Rightarrow$ /i/

/int/ << /in/ < /i/

So we could say that the intra-syllabic clusters were subjected to organizational constraints. A more detailed study about phonetic nature of syllabic constituents was necessary to better understand structural constraints.

3. INTERACTION BETWEEN SYLLABIC SEGMENTS

To shed light on selection and restriction constraints with in syllable structures, we were interested in the relation between segments, which appeared in the same syllable, or in two consecutive syllables. In order to better observe the syllabic structures, we created co-occurrence matrixes. We decided to group segments according to their phonetic features (six manners and nine places of articulations for consonants [8], [9], and three places for vowels) in order to be able to compare our results with previous databases [10], [11]

We counterbalanced observed syllable frequency by the frequency of the segments of this syllable (expected syllable). For example, frequency of /ta/ was divided by the product of /t/ and /a/ frequencies. So we have some ratios that showed what type of syllable was favored (ratio > 1).

3.1. Interaction between onset and nucleus

For example for the CV structure, we noted that we have three favored combinations:

	BILABIAL	CORONAL	VELAR	OTHERS
FRONT	0.84	**1.14**	0.86	0.92
CENTRAL	**1.08**	0.94	0.99	1.11
BACK	1.00	0.99	**1.18**	0.88

Table1: Ratio between observed and expected syllables for the CV combinations in the all 14 languages (χ^2 significant, $p < 0.001$ for each column).

These results agreed with MacNeilage and Davis [12] about babbling and also ten natural languages. This lets us suppose that languages favoured combinations in which articulators do not make extensive movements from consonant gesture to vowel gesture.

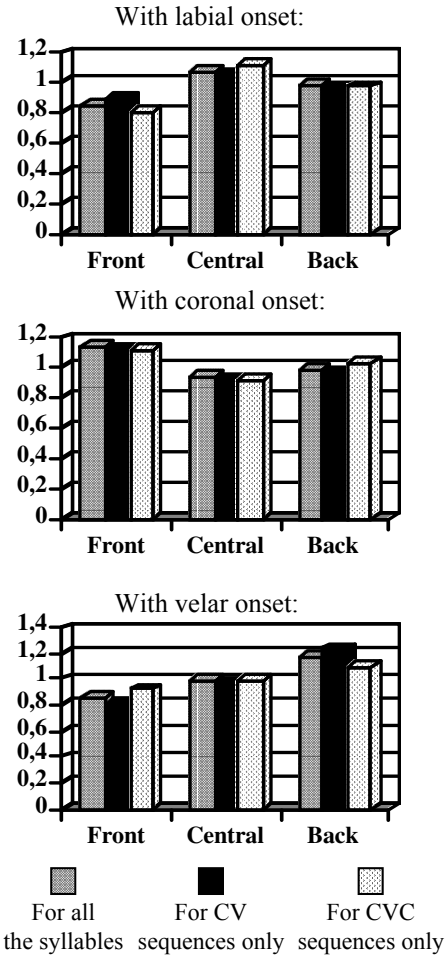

Figure 1: Graphs of the interactions between onset and nucleus for different syllable structures.

Previous analyses of CV structures did not include other syllabic structures. So we wanted to know if the presence or absence of coda influenced the relationship between onset and nucleus in a syllable. Figure 1 shows that there was no influence of the coda.

3.2. Interaction between nucleus and coda

Analysis of the interactions between nucleus and coda, showed that there was the same relationship as in CV structures. As for CV combinations, we analyzed all the syllabic structures, and our results did not change because of presence or absence of onset. Languages seemed to favor combinations in which articulators do not make extensive movements from vowel gesture to consonant gesture.

	FRONT	CENTRAL	BACK
BILABIAL	0,54	**1,28**	1,13
CORONAL	**1,24**	0,91	0,95
VELAR	0,76	0,84	**1,37**

Table 2: Ratios between observed and expected syllables for VC combinations in the all 14 languages (χ^2 significant, $p < 0.001$ for each column).

We also could observe that the link between vowel and consonant seemed more important in VC than in CV. It confirms the phonological hypothesis of rhyme.

3.3. Interaction between onset and coda in CVC or in consecutive onsets in CV.CV

Our predictions for interactions between vowel and consonant (in CV and VC) were that favored syllables would be the ones with onset and coda in the same articulatory place, and the vowel which required the less articulatory movement.

We explored the relation between two consonants within syllables. We focused on less complex onsets and codas. We observed that various articulation places for the two consonants were favored. For example, [pap] and [tat] syllables was less frequent than [tap] or [pat]. So we could conclude that there is no place parsimony between onset and coda in CVC structures contrary to our results between C and V that led us to formulate the hypothesis.

	BILABIAL	CORONAL	VELAR
BILABIAL	0,51	**1,15**	**1,10**
CORONAL	**3,03**	0,91	**1,13**
VELAR	0,97	**1,15**	0,63

Table 3: Ratios between observed and expected syllables for C_C combinations in the all 14 languages (χ^2 significant, $p < 0.001$ for each column).

However, some CVC structures were more frequent than others:

- bilabial-coronal
- coronal-velar
- coronal-bilabial
- velar-coronal

If we focused on combinations with bilabial and coronal consonants, we could see that one combination is more preferred. This relationship between bilabial and coronal consonants exists both in CV and CV.CV structures (Table 4).

	BI	CO	VE
BI	65	**241**	83
CO	**577**	1005	582
VE	104	253	75

Table 4: Occurrence matrix for the C_C combinations in CV.CV words in 10 languages.

We calculated the following ratio: number of bilabial_coronal sequences divided by number of coronal_bilabial sequences. Our results are as follow:

(bilabial-coronal) / (coronal-bilabial) = 2,39 for CV.CV
(bilabial-coronal) / (coronal-bilabial) = 1,44 for CVC

We noted that the ratio is larger for CV.CV structures than for CVC structures., MacNeilage and Davis [12] had a much bigger ratio for these relationships (ratio = 2.55). They coined the term LC effect and noted that it was absent in babbling, but appeared with the first words and remained present in adult languages.

4. DISCUSSION

At first, the study of different types of syllabic structures permitted us to confirm extend some implicational laws, which showed that frequency of syllables was not random: the most complex syllables were the less frequent. Future study should focus on segments which could appear in clusters to better understand the constraints of complex syllables.

Next, we compared our work about favored sequences with previous studies. Kawasaki [10] and Janson [11] analyzed the relationship between consonants and vowels in CV structures. They proposed two possible explanations. Kawasaki explained his results by perceptual properties: the disfavoured sequences have less than optimal properties for efficient perception. Janson proposed an articulatory characterization: the favoured sequences were these in which the articulators do not make extensive movements from the consonant gesture to the vowel gesture.

Our results do not totally agree with Kawasaki and Janson, but confirmed those of MacNeilage and Davis [12] about infant production (babbling and first words), 10 natural languages and proto-forms. In their theory, the mandibular cycle provided an articulatory frame for syllabic organization because it stimulated movements of the other supra-glottal articulators.

So, we could support the results of MacNeilage and Davis about the presence of coda in syllables. In CVC structures the most favored types were those in which onset and coda did not have the same articulatory place. This place no-parsimony principle between onset and coda must have several explanations: 1) acoustical efficiency and maximal distinctiveness between beginnings and ends of syllables; 2) the perceptual advantage of onsets over codas [13]; 3) difficulty of producing two identical movements successively.

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Our results also confirmed the findings of MacNeilage and Davis about the LC effect. We showed that the LC sequence appears in CV.CV sequences and in CV structures. This effect could be explained by minimization of cost in the mandibular open-close movements [12]. Another hypothesis could be that the possibility of coarticulation was greater in bilabial-coronal structure than in coronal-bilabial.

5. CONCLUSION

The hypothesis of syllabic unit existence has been reinforced by different studies such as those describing lenition and fortition principles, experimental data on articulatory strength [14], [15], and syllabic organization in language games. The relationship observed in our data between elements within syllables confirmed this hypothesis. More consonants appeared in onset than in coda; some syllabic types were more frequent in initial position than in final; implicational laws constrained structural complexity and remained true if we considered the nature of syllabic elements; all these results expressed strength constraints for intra-syllabic position. Moreover, the verification of the LC effect for the CV.CV sequences permitted a hypothesis for inter-syllabic organization at the lexical level.

In a reasoning that would take root form into substance, the data analysis was complementary to studies which would describe articulatory and perceptual characteristics of syllables. Thus, phonological asymmetries observed in languages have often been presented as results of perceptual properties [3] or of articulatory properties [16], [17]. We have shown that the parsimony principle does not function for syllables. This result seemed to refute the concept of minimal cost in the production of syllables [12], but seems back up the hypothesis of search for acoustical efficiency. Several principles appeared to intervene in formation of the syllabic unit. Data for languages will probably provide some elements in the establishment of rules and weights for these different principles.

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