Sonority and Its Role for Syllabification

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Abstract: This paper contends that a better explanation of the distribution and sequencing of segments within the syllable will follow from a better understanding of the issues relating to the representation of sonority. Briefly summarizing theoretical constructs in both phonological and phonetic standpoints, focus will be given on the three aspects of sonority which factor in the understanding of the concept: the sonority sequencing principle, the sonority hierarchy, and its acoustic manifestation. Seemingly disparate proposals on syllabification relating to sonority are logically independent, but together they form an intriguing and appealing program for research to be made.
Key word: syllable, sonority principle, sonority hierarchy.

0. Introduction

Early generative phonology was characterized by a linear organization of segments and a set of phonological rules. In recent years, the field of phonology has developed new theories, including autosegmental theory, metrical theory, lexical phonology, and prosodic phonology. While standard generative theory described the input to the phonology consisted solely of the output of the syntax, the model system of prosodic phonology fundamentally differs from the model of traditional generative phonology in that prosodic phonological representations consist of a set of phonological units organized in a hierarchical fashion unlike the linear representations of traditional generative phonology. After outlining the theoretical frameworks of phonological theories and presenting crucial differences of the principles among them, consideration is first focused on the domain of syllabifications in respect to the internal phonological structure, so that plausible ways of empirical phonetic verification can be examined and probed in support of a still more explanatory phonological theory.

1.0 On the notion of 'syllable'

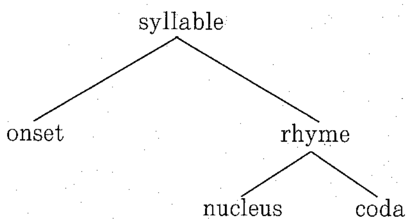
Speech is organized into syllables. Although nearly everybody can identify syllables, almost nobody can define them. It is difficult to state an objective procedure for locating the number of syllables in a word or a phrase in any language. Some people will say that the word 'meal' contains two syllables, but others will consider them to have one. There are words difficult to be agreed upon in determining the number of syllables contained, but it is important to remember that there is no doubt about the number of syllables in the majority of words. However difficult it may be to define what they are and to identify them consistently, a 'syllable' is a notion that people recognize intuitively. It is a unit larger than a single segment and smaller than a word, and this characteristics can be described from both a phonetic and a phonological point of view, one of which is distinguished from the other, although the differentiation is not yet agreed upon by all scholars.

1.1 Phonological standpoint of 'syllable' and syllabification

A phonological syllable is a conventional unit which is a group of sounds that constitutes the smallest unit of the rhythm of a language. These phonological syllables differ from language to language[1]. In English, for example, it is theoretically possible to make a single syllable as CCCVCCCC, whereas the syllable structure of the standard Japanese is generally described as V, CV, CVV, CVQ, and CVN[2]. The syllable, in this view, is considered an important abstract unit in explaining the way vowels and consonants are organized within a sound system[3].

Kiparsky (1979), Selkirk (1980), Clements & Keyser (1983) and others have characterized the internal organization of the syllable as in (1).

(1)



Their typological studies have included basic generalizations as follows: all languages have syllables with onsets; many languages require all syllables to have onsets in surface representation; no language requires all syllables to have codas. Each syllable has a nucleus, and language-particular conditions govern the class of possible onsets and codas.

In prosodic phonology, however, it is claimed that the syllable is the terminal category of the prosodic hierarchy. This does not mean that it excludes the possibility that the segments may be grouped into other subsyllabic units, such as onsets and rhymes. Admitting the existence of internal structure within a syllable, it attempts to proclaim that an exclusion of segments, onsets, and rhymes should be made from the prosodic hierarchy, on the grounds that they are not organized in accordance with the principles governing the other units above the syllable level, and do not serve as the domain of application of phonological rules. Nespor & Vogel (1986) gives the case of ambisyllabic segments, where they find an element that is at the same time a member of the rhyme of one syllable and the onset of another[4]. Ito (1989) argues for Prosodic Theory with the four principles: Maximality, Directionality, Prosodic Licensing, and Extraprosodicity, showing that the Skeletal Rule Theory of epenthesis leads to many undesirable redundancies. She takes the position that syllabification is based on templates and well-formedness conditions rather than on specific syllable-building rules.

1.2 Phonetic standpoint of 'syllable'

In phonetics, several attempts have been made to identify syllables on the basis of the amount of articulartory effort needed to produce them. Saussure (1959) classified sounds by the size of the breath passage, and attempted to locate the breaking points of syllables by noting whether the vocal organs were closing or opening. He claimed that the breaking point of syllables is located in between the implosive and the explosive. Stetson (1959) argued that each syllable corresponds to an increase in air pressure, air from the lungs released as a series of chest pulses, which is known as the pulse or motor theory of syllable production. Jespersen (1904) presented an alternative phonetic approach, known as the prominence theory[5]. This defines the syllable in auditory terms, arguing that some sounds are intrinsically more sonorous than others, and that each peak of sonority corresponds to the center of a syllable. He asserts that a syllable is a sequence of sounds between two adjacent points of minimum sonority in utterance. Ladefoged (1975) also asserts that one way of tying to find an adequate definition of a syllable should be by defining the syllable in terms of the inherent sonority of each sound. He claims that one possible theory of the syllable is that peaks of syllabicity coincide with peaks of sonority, and this theory would explain why people agree on the number of syllables in the majority of words.

2.0 On the notion of 'sonority'

'Sonority' is a word to describe a speech sound, and many a proposal has been made concerning the role of sonority in syllable structure. Like the syllable itself, the proper characterization of 'sonority' remains controversial in both phonological theory and phonetics. From a phonological standpoint, Carnie (1994) asserts that 'sonority' is derived from the markedness relations in the feature geometry, and that the calculation of sonority is determined not by an arbitrary ranking, but rather upon a simple calculation of feature content. Jespersen (1904) defined 'sonority' as a general combination of factors to qualify the total impression of a sound[6]. As opposed to his subjective definition, Jones (1957) gave a definition that 'sonority' is the degree of the greatest distance of audibility of a sound when pronounced with the same length, stress, and pitch[7]. Ladefoged (1975) says that the sonority of a sound is its loudness relative to that of other sounds with the same length, stress, and pitch, and the loudness of a sound mainly depends on its acoustic intensity.

2.1 Sonority Sequencing Principle

The role of 'sonority' in syllable structure has long been discussed by many researchers, and they all agree that syllables generally conform to some principle of sonority sequencing. As is described in Selkirk (1982), there is a segment, in any syllable, constituting a sonority peak that is preceded and/or followed by a sequence of segments with progressively decreasing sonority values. When sonority values are assigned to the segments of a representation, it is the case that peaks of sonority are the segments that are assigned to be the nucleus of the syllable. Clements (1987) refers to this organization as Sonority Sequencing Principle, which states: 1) typically all local peaks of sonority are syllable nuclei; 2) all syllable nuclei are sonority peaks, and thus are higher in sonority than onsets, or codas, if they have codas. This sonority theory characterizes syllable-internal phonotactics and its well-formedness.

2.2 'Sonority' as an acoustic parameter

Ladefoged (1975) claims that 'sonority' is basically an acoustic phenomenon. The sonority of a sound can be estimated from measurement of the acoustic intensity of a group of sounds that have been uttered on comparable pitches and with comparable degrees of length and stress. It is possible to compute average intensity values for individual sounds. According to the average values for individual speech sounds in the English language, estimated by Fry (1979), open vowels are the most intense sounds, followed by close vowels and continuants, the weak fricatives and plosives occurring at the opposite end of the scale. These values expressed in decibels are shown in (2), related to the sound with the lowest intensity [θ], which has the intensity value of zero.

(2)	ɔː	ɒ	ɑː	ʌ	ɜː	a	ʊ	e	iː	uː	ɪ
	29	28	26	26	25	24	24	23	22	22	22
	w	r	j	l	ʃ	ŋ	m	tʃ	n	dʒ	ʒ
	21	20	20	20	19	18	17	16	15	13	13
	z	s	t	g	k	v	ð	b	d	p	f
	12	12	11	11	11	10	10	8	8	7	7

2.3 'Decibel' as a unit for measuring 'sonority'

The extent of to-and-fro movements of an air particle is known as the amplitude of the vibration. The greater the amplitude, the greater the intensity of the sound, and along with other factors, such as frequency and duration, the greater our sensation of loudness, which does not relate to any one of its acoustic components independently. To measure the loudness of a sound, we need to take into account the contribution of both amplitude and frequency, factors that relate to the energy with which the sound is produced. The term 'intensity' is used to refer to the overall power of a sound. To measure sound intensity, we need a basic, internationally accepted reference level for sound pressure in air. Departures from this reference level are then measured in units known as decibels (dB)[8]. Sound intensities are related to each other as ratios, using a logarithmic scale, that is, an increase of 10 dB is equivalent to a doubling of loudness. For example, 20 dB is twice as loud as 10 dB, and 30 dB is twice as loud as 20 dB.

3.0 Sonority Hierarchy (SH) and Relative Sonority

The way phonological strings are organized into syllables depends on the relative sonority of segments, and there is a sonority hierarchy that ranks classes of segments or the features that characterize them in terms of relative sonority. The concept of every peak of sonority corresponding to distinct syllable peak has been variously known as Sonority Sequencing Principle (Clements), Sonority Sequencing Generalization (Selkirk), and Sonority Principle (Goldsmith), etc. The sonority hierarchy is a statement of the relative inclination of the segments of a language to be the nucleus of their particular syllable, and it has been used to characterize language-specific notions of syllable well-formedness. Segments that are highly sonorous, vowels in particular, are strongly inclined to be found in syllable nuclear position. In some languages, they always appear in nuclear position, while in others they can be forced from nuclear position only by competition among them for appearance in that position. Something more sonorous can edge out something less sonorous in the competition for appearing in syllable nucleus position. Similarly, low sonority sounds, such as obstruents, typically cannot appear in nuclear position in most languages, and frequently cannot appear in coda position either, which implies that they must appear in onset position. In some languages, even obstruents can appear in nuclear position, but again only if nothing more sonorous is available in the nearby phonological neighborhood.

3.1 Relative Sonority

Ladefoged classified sounds according to degrees of 'sonority' as in (3).

(3) vowels [−high] > vowels [+high] > liquids > nasals > voiced fricatives > voiceless fricatives > voiced stops > voiceless stops

In order to make the sonority scale more scientific, the relative sonorousness of single sounds was measured statistically. The relative values of single sounds obtained are shown in (4), giving the value of 1 to the weakest sound [θ] and the ratio of the weakest to the strongest is 680, which is about 68 dB[9].

(4) Relative Phonetic Intensity of the Fundamental Speech Sounds[10]

ɔ:	ɒ	ʌ	æ	oʊ	ʊ	eɪ	e	u:	ɪ	i:
680	600	510	490	470	460	370	350	310	260	220
r	ɪ	ʃ	ŋ	m	tʃ	n	dʒ	ʒ	z	s
210	100	80	73	52	42	36	23	20	16	16
t	g	k	v	ð	b	d	p	f	θ	
15	15	13	12	11	7	7	6	5	1	

Avoiding the disagreements concerning the physical basis of sonority, and rather than restricting the use of sonority just to account for syllable-internal phonotactics, Parker (1989) takes the concept one step further and formalize it in terms of specific word-level grid configurations, that is, inter-syllabic phonotactics. He sees 'sonority' as a multi-valued continuum rather than a traditional binary feature and considers it as reflection of relative phonological parameters, positing the universal scale of relative sonority as in (5).

(5) low vowels > mid vowels > high vowels > glides > rhotics > laterals > nasals > obstruents (voiced fricatives > voiceless fricatives > voiced stops > voiceless stops)

He first gives the values to each grid in this universal scale of relative sonority, from the value of 11 for the most sonorous down to the value of 1 for the least sonorous, and then translates it into a language-specific grid. In his Sonority Level (SL) Phonology, the sonority grid for the Chamicuro language is given as in (6), and the Glide Formation process /i, u/ ⟶ [y, w] / _____V, for example, is formalized as in (7).

(6) low vowel:9 > mid vowel:8 > high vowel:7 > laryngeal:6 > glide:5 > lateral:4 > nasal:3 > fricative:2 > stop:1

(7) [SL 7] ⟶ [SL 5] / _____ [≥ SL 7] (=23)

It is worth noting here that both Ladefoged and Parker proclaim that sonority indices of their types reflect only universal tendencies, not absolute constraints on permissible phonotactic arrangements of segments in every language.

3.2 Alternatives to Sonority Hierarchy (SH)

Sonority hierarchy well explains the phonotactics of the English words such as 'visit, compensation', each of their syllable peaks being more sonorous than the surrounding sounds. On the contrary, the prediction of SH is violated in the case of a word with an English cluster such as 'st-' in the word 'strength', whose syllable structure is CCCVCCC. As a resolution, Selkirk (1982) attempts to solve this contradictory case of [st] sequence by allowing [st] ([s] and [+obstruent]) to qualify as a single consonant, but it can not be denied that it is an ad hoc resolution, unless it is, in any way, empirically verified why the such clusters are allowed in that specific sound sysrem. Rice (1993) argues for a feature Sonorant Voice (SV) to replace the traditional feature [sonorant], claiming that a single feature [voice] is not the appropriate feature to capture the type of voicing found in sonorants, and shows that the traditional feature [sonorant] can occur in obstruents.

Ohala (1992), one of a few who have questioned the theoretical validity of 'sonority', makes a proposal that rather than posit a single parameter, sonority, which he says has never been identified empirically, attention should be focused on several acoustic parameters which are well known and readily measured in the speech signal, such as amplitude, periodicity, spectral shape, and F0. He also suggests that we should concentrate on the modulations in the relevant parameters created by concatenating one speech sound with another, rather than focus on some alleged intrinsic value that individual speech sounds or sound types are supposed to have.

Goldsmith & Larson (1990) present a somewhat different view, proposing a synthesis of rules and representation, in a fashion that is similar to recent work in connectionist modeling. They provide formal models, in general computer-implemented models, that have an internal dynamic of their own. In their scheme, a given word is represented by a set of units, each assigned an activation level between -10 and $+10$, and these units form a network. These networks always and automatically have the property that when a representation is input to them, they quickly move out of that state into some other nearby state, one which they prefer. They treat sonority as a scalar dimension, and give the proposition that the sonority of a segment is context-dependent and the recalculation of context-sensitive sonority is a language-particular arithmetic notion based on language-particular parameters (α, β) and a simple local calculation. In their algorithm, as that in (8), the cases where (α, α)=(0, 0) works are the cases where the simple Sonority Principle holds.

(8) $a_i^{t+1} = (\text{inherent sonority})_i - (\alpha \cdot a_{i+1}^{t}) - (\beta \cdot a_{i-1}^{t})$

a_i represents the activation level of the i^{th} unit, and t 'time'.

4. Concluding Remarks

A fundamental distinction in work in phonological theory over the past years has been that between phonological rules and phonological representations. Some have drawn the conclusion that all rules can be dispensed with entirely; some have taken the view that the development of geometrical models led to a qualitative simplification of the rule formalisms, to the point where geometrical simplicity becomes the goal that guides the development of phonological theory; some have proposed to incorporate a multi-dimensional acoustic parameters in the use of sonority hierarchy for syllabification; and others have proposed a model utilizing computational networks that provides a better device for encoding sonority relationships. To understand syllables and their internal phonotactics in light of the issues relating to the sonority, it seems helpful to reconsider the distinction between phonological and phonetic standpoints, and between static and dynamic approaches. Whereas linguists have not been able to agree on the definition of the syllable, there is a fairly high level of agreement among apparently disparate analyses on sonority.

Notes

1. According to the differences in their rhythmic units, languages have been traditionally classified into three different types: stress-timed, syllable-timed and mora-timed. (Both 'syllable' and 'mora' are prosodic units, and 'mora' is defined as a quantitative unit smaller than a 'syllable'.) In the case of stress-timed languages, one of which is English, the interval between strong stresses, generally called a 'foot', is said to have an equal duration regardless of the number of syllables contained in the interval, while syllable- or mora-timed languages, like French and Japanese respectively, keep equal duration for a syllable or a mora.

2. 'Q' and 'N' are syllabic consonants called 'Sokuon' or 'Hatsuon' respectively. Using a quantitative unit 'mora', CV is counted as one, whereas CVV, CVQ, and CVN as two.
3. The number of possible syllables varies greatly from language to language. The UPSID (The University of California, Los Angels Phonological Inventory Database) survey includes: Hawaiian 162, Rotokas 350, Yoruba 582, Tsou 968, Gã2331, Cantonese 3456, Quechua 4068, Vietnamese 14430, Thai 23638. (Crystal p.164)
4. Instead of syllabifying a word 'happy' as [hæ.pi] or [hæp.i], [p] is considered to be ambisyllabic and at a same time belong to a member of the rhyme of the left-hand syllable and the onset of the right-hand one.
5. The problem with this prominence theory is that other factors than sonority, like 'pitch' of a sound, enter into the definition of prominence. It also fails to give a clear indication of where the boundary between syllables falls.
6. Jespersen classified sounds according to degrees of 'sonority' as follows: (In order from low to high) (1) voiceless consonants; stops, fricatives, (2) voiced stops, (3) voiced fricatives, (4) nasals and laterals, (5) trilled [r], (6) narrow vowels, (7) half-narrow vowels, (8) wide vowels.
7. According to his scale, sonority becomes smaller in the order of; open vowels, close vowels, voiced consonants, voiceless consonants.
8. It has been estimated that the human ear is sensitive to about 10^{13} units of intensity.
9. The power of each sound varies according to its position or the intensity of utterance, but the relative sonorousness of single sounds was measured by obtaining the average value of the power of sounds produced by about 60 persons by means of variously combined sound samples. (Onishi, p.512)
10. Phonetic Intensity: The energy of the sound passing through a unit area per unit time. The value is expressed in watt per square centimeter. (ibid.)

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