The phonology of periodicity: Sonority as the perceptual integration of acoustic energies

All languages impose certain restrictions on the organization of speech sounds into syllables. This phonotactic behavior has been traditionally attributed, at least in part, to the notion of sonority. While there have been many attempts to define sonority phonetically (for a thorough overview see Parker 2002), a consistent phonetic correlate has not yet been found.

The current paper suggests that sonority is correlated with the perceptual sensation of pitch (*pitch intelligibility*), acoustically defined as periodic and aperiodic energy in the signal. (Quasi-)periodic energy in speech is the result of phonation (*voicing*) due to vibration of the vocal folds, and it is the main contributor to pitch intelligibility. Aperiodic energy is the result of turbulent airflow, due to constrictions along the vocal tract, and it can be detrimental to pitch intelligibility. Other things being equal, the relative pitch intelligibility values of major segmental categories correlate with standard sonority scales (see Tables 1-2, next page).

Correlations between sonority and periodic energy have been suggested in the past, with prominent examples including Lass (1984), Ladefoged (1997) and Heselwood (1998), going back even to the Sanskrit grammarians (see Donegan 1978 and Nathan 1989). The present proposal deviates from these earlier accounts in that it integrates different types of acoustic energy into a single scale of perceptual pitch intelligibility, and treats sonority in terms of energy that *attracts* syllabic nuclei when accumulated to a sufficient degree.

Attraction of syllabic elements is not novel in prosodic phonology. In *weight sensitive* systems, stress is attracted to heavy syllables. In comparable terms of the current proposal, increased vocalic duration attracts the most prominent nucleus – that of the stressed syllable. Increase in duration and/or intensity, the main phonetic cues for stress (Fry 1955, 1958), indeed enhance periodic energy of sonorant portions over and above what the segmental makeup delivers. The proposal here is therefore for a single mechanism whereby *sufficiently* periodic energy attracts nuclei and *enhanced* periodic energy attracts prominent nuclei.

Nucleus attraction makes different predictions than the *Sonority Sequencing Principle* (SSP), the most well-established principle relating to sonority. The SSP defines the terms *rise*, *fall* and *plateau* for successive strings of segments, with the simple idea that syllabic margins (onset/coda) optimally rise in sonority towards the nucleus. The SSP accounts well for types of sequential *slopes* but it is blind to the absolute sonority levels of segments (i.e. the *intercepts* of the slopes). To exemplify this problem, consider the onset clusters in (1). In terms of the SSP they are identical (same sonority; *plateaus*) but the more sonorous plateaus on the right should be regarded as more marked and illformed complex onsets.

(1) **sf**V < **zv**V < **nm**V < **jw**V

A general principle of nucleus attraction (see 2) can discriminate between the clusters in (1), given that the more sonorous plateaus entail greater competition for nucleus attraction between the vowel and C_1. Crucially, violations in this model are proportional to the degree of competition within syllables such that greater competition intensifies illformedness.

(2) Nucleus Attraction Principle: *Every sufficiently periodic peak in the stream of speech attracts one unique nucleus*

Note that (2) is an asymmetrical restriction that defines criteria for perceptual syllabicity among portions that are sonorous enough (i.e. sufficiently periodic) to compete for attraction. As a result, widely attested cases of sC-clusters (e.g. **st**ar) simply do not incur violations, contra to the SSP, due to the minimal nucleus attraction of voiceless segments. However, when sonorant segments are involved, the potential competition for nucleus attraction within syllables yields an elaborate set of predictions, much richer than the SSP. All the examples in Table 3 (next page) incur identical SSP violations (onset fall) but differences in competition for nucleus attraction suggest systematic improvements in terms of syllabic wellformedness.

The current proposal is functionally motivated: A bottom-up view is supported by the fact that the human auditory system has evolved with dedicated mechanisms to detect periodicity (e.g. *phase locking*; Wever and Bray 1937); A top-down view is supported by the fact that pitch events are required at some level of the phonology of all languages (tone, intonation etc.). The fact that the syllabic/moraic unit is generally taken to be the anchor for pitch events further strengthens the functionality of this proposal, which ties periodicity to syllabicity.

*Table 1. Correlating sonority with pitch intelligibility (PI) as a measure of periodicity**

	Periodic Energy	**Aperiodic Energy**	**PI/ Sonority**
Vowels	Very strong	(Minimal)	↑
Semivowels/ glides	Strong	(Minimal)	
Liquids	Mid	(Minimal)	
Nasals	Weak	(Minimal)	
Voiced obstruents	Weak	Weak	
Voiceless obstruents	(Minimal)	Strong	

To account for divisions between stops and fricatives, the transience of the release phase in stops (short burst) should be considered as detrimental to pitch intelligibility (see Table 2).

Table 2. Obstruents' pitch intelligibility (PI) as a measure of periodicity and transience

	Periodic Energy	**Aperiodic Energy**	**Transient release**	**PI/ Son.**
Voiced fricatives	Weak	Weak	(No)	↑
Voiced stops	Weak	Weak	Weak	
Voiceless fricatives	(Minimal)	Strong	(No)	
Voiceless stops	(Minimal)	Strong	Strong	

Table 3. Paths for improvement of syllabic wellformedness in complex onset falls

Onset change	**Description**	**Weaker competition due to**	**SSP predicts**
lpV → **zp**V	C_1 decreases w.r.t. C_2	Decrease in degree of slope	No difference
lpV → **lv**V	C_2 increases w.r.t. C_1	Decrease in degree of slope	No difference
lmV → **zb**V	C_1 & C_2 decrease together	Decrease in level of intercept	No difference
lbV → **sp**V	C_1 decreases more than C_2	Decrease in slope & intercept	No difference

* *Periodicity* makes reference to both periodic and aperiodic energy (see Rosen 1992).

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