THE EFFECTS OF PHONOLOGICAL STRUCTURE ON THE ACOUSTIC CORRELATES OF RHYTHM

Shelece Easterday, Jason Timm & Ian Maddieson

Department of Linguistics, University of New Mexico, USA
seasterd@unm.edu; jtimm@unm.edu; ianm@berkeley.edu

ABSTRACT

The relationship between the %V, ΔC, and ΔV metrics of rhythm and the phonological characteristics they are generally believed to relate to is directly investigated. A cross-linguistically diverse sample of languages is examined to determine whether languages which pattern similarly according to phonological features, including range of allowable syllable structure, presence of phonemic vowel length contrast, and presence of vowel reduction, necessarily pattern similarly in their measured %V, ΔC, and ΔV values. Of these features, syllable structure is found to have a significant effect on the indices ΔC and %V and vowel length contrast is found to have a significant effect on the variability index ΔV. Vowel reduction has no significant effect on the metrics.

Keywords: rhythm classification, acoustic correlates of rhythm, syllable structure, typology

1. INTRODUCTION

Dauer [3], Roach [9] and others have suggested that factors such as consonant clustering, the presence or absence of contrastive vowel length, vowel reduction, and salient stress are important contributors to perceived linguistic speech rhythm. The metrics %V and ΔC which measure the proportion of vocalic intervals and the standard deviation of consonantal intervals in speech were proposed by Ramus, et al. [8] as likely indices of traditional rhythmic categories. It was suggested that these metrics directly relate to syllabic structure: high %V/ΔC quotients imply relatively simple allowable syllable structure, while low %V/ΔC quotients reflect more complex syllable structure, the intuition being that more complex syllable structure is reflected in more variability in the duration of consonantal intervals and that such variability implies the potential for less of the speech signal being vocalic.

Ramus et al. (1999) observe a strong correlation between %V and ΔC in their data, which consists of 7 Western European languages and Japanese. Easterday and Timm [4], examining a 10 language sample representing 8 language families from the Pacific Northwest and Papua New Guinea, demonstrate that variation in the metrics extends far beyond the portion of the %V, ΔC space occupied by these European languages and Japanese, but that the strong linear relationship between %V and ΔC remains. In fact, Cassandro, et al. [2] have suggested that such a relationship is cross-linguistically universal.

The third index calculated by Ramus et al., ΔV, the variation in vocalic intervals, is not found in the previous studies to correlate with %V or ΔC, but instead this metric may reflect phonological characteristics directly related to vowel length, such as contrastive vowel length, unstressed vowel reduction, and non-phonemic vowel lengthening.

2. RESEARCH QUESTIONS

The relationship between the %V, ΔC, and ΔV indices (or similar variants [6]) and the phonological characteristics they are believed to relate to is not directly investigated in the previous literature, but is inferred post-hoc. In the languages used in the Ramus et al. sample a single language may exhibit several of the factors believed to affect rhythm, for example, Dutch has complex syllables, contrastive vowel length, strong stress differences and vowel reduction in unstressed syllables. By contrast, this paper presents a preliminary test in a genetically and a really diverse sample of languages of specific individual factors expected to affect variation in the metrics developed by Ramus et al. We examine specifically whether languages which allow a similar range of syllable structures necessarily pattern similarly in their measured %V, ΔC, and ΔV values. We also examine whether two other factors, namely contrastive vowel length and vowel reduction, when controlled for, affect the metrics independently or in interaction with syllable complexity or each other.

A corollary to this line of inquiry is to determine whether the strong inverse relationship

between %V and ΔC noted in the literature is in fact a cross-linguistically valid universal. Easterday and Timm have shown this relationship to be highly significant (r=-.94), suggesting that consideration of both metrics may be unnecessary. However, if this relationship proves to vary according to factors such as syllable structure, contrastive vowel length, and vowel reduction, this putative universal must be reconsidered.

3. METHODS AND MATERIALS

Speech samples from twenty-two genetically and areally diverse languages were analyzed for this study. The sample consists of seven languages with simple syllable structure and fifteen with complex syllable structure, using the definitions of syllable complexity in Maddieson [7]. Simple syllables are no more elaborate than CV. Complex syllables have two-obstruent onset clusters and/or two-consonant codas or longer clusters in either position. A language's classification is determined by the most complex syllable it permits. Phonemic vowel length contrasts are present in half of the languages, and vowel reduction occurs in seven of them. Details of the language sample are given in Table 1. These classifications were determined by reference to grammars of each language.

The audio files are from the Global Recordings Network [5] or The Languages and Cultures of Northeast Eurasia [10] websites, and consist of excerpts of spoken narrative from Biblical and mythological genres. Each language in the sample is represented by audio recordings from two different speakers. Approximately thirty seconds of consonantal and vocalic intervals were extracted from the recording of each speaker using Praat [1] following the procedure outlined in Ramus, et al. [8].

Table 1: Languages in sample. Metric values for each language are averaged over both speakers.

Language Code	Language	Family / Region	Syllable Structure	Contrastive vowel length?	Vowel reduction?	%V	ΔC (msec)	ΔV (msec)
KH	**Khasi**	Austro-Asiatic	Complex	Yes	No	**48.8**	**46.6**	**50.0**
NP	**Nez Perce**	Penutian	Complex	Yes	No	**48.6**	**59.6**	**55.0**
PO	**Ponapean**	Austronesian	Complex	Yes	No	**52.6**	**41.8**	**41.8**
SH	**Sheko**	Afro-Asiatic	Complex	Yes	No	**54.6**	**49.6**	**68.3**
AM	**Ayutla Mixtec**	Oto-Manguean	Complex	Yes	Yes	**57.3**	**40.2**	**63.4**
BR	**Bruu**	Austro-Asiatic	Complex	Yes	Yes	**52.9**	**57.0**	**71.1**
KT	**Kuuk Thaayorre**	Pama-Nyungan	Complex	Yes	Yes	**51.1**	**64.1**	**61.6**
QI	**Qiang**	Sino-Tibetan	Complex	Yes	Yes	**56.2**	**39.3**	**50.0**
NA	**Nambikuara**	Nambikuaran	Complex	No	Yes	**60.0**	**47.3**	**54.8**
TA	**Tamazight**	Afro-Asiatic	Complex	No	Yes	**44.8**	**63.9**	**41.1**
TE	**Temne**	Niger-Congo	Complex	No	Yes	**49.6**	**41.8**	**51.9**
AP	**Apinaje**	Macro-Ge	Complex	No	No	**56.4**	**52.3**	**53.3**
CH	**Chukchi**	Chukotko-Kamchatkan	Complex	No	No	**47.8**	**82.0**	**63.1**
LA	**Ladakhi**	Tibeto-Burman	Complex	No	No	**43.3**	**50.1**	**36.4**
MG	**Maung**	Australian	Complex	No	No	**59.7**	**29.0**	**67.2**
EK	**Ekari**	Trans-New Guinea	Simple	Yes	No	**59.5**	**33.4**	**53.1**
MA	**Maori**	Austronesian	Simple	Yes	No	**60.1**	**32.1**	**52.5**
TO	**Towa**	Kiowa-Tanoan	Simple	Yes	No	**56.8**	**42.1**	**58.1**
CM	**Chalcatongo Mixtec**	Oto-Manguean	Simple	No	No	**53.7**	**42.8**	**53.0**
GU	**Guaran í**	Tupian	Simple	No	No	**55.0**	**43.6**	**40.7**
HA	**Hadza**	Hadza	Simple	No	No	**58.3**	**30.1**	**50.9**
SA	**Sango**	Niger-Congo	Simple	No	No	**56.5**	**38.1**	**37.8**

4. RESULTS

4.1. Syllable structure

The mean %V, ΔC, and ΔV values obtained for languages with complex vs. simple syllable structure are shown in Table 2.

Table 2: Mean %V, ΔC, and ΔV values as a function of syllable complexity. ΔC and ΔV values measured in msec.

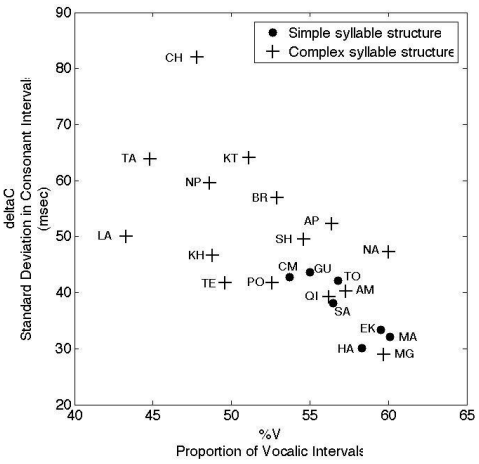
Syllable Structure	%V	ΔC	ΔV	%V/ ΔC
Complex (N = 15)	52.2	51.1	55.1	1.02
Simple (N = 7)	57.1	37.5	49.5	1.52

The ΔV values do not vary greatly or significantly as a function of syllable complexity;

variation in vocalic intervals is essentially comparable for languages whether they have complex or simple syllable structure. However, syllable structure has a strong significant effect on both ΔC and %V; variation in consonantal intervals is decidedly higher in languages with complex syllable structure, while proportion of vocalic intervals is higher in languages with simple syllable structure. In a multiple regression analysis, syllable structure has a significant effect on both ΔC and %V at the p<.005 level, but there is no similar effect on ΔV.

While there is a strong correlation between %V and ΔC in the languages sampled (r =-.598, p=.000; see Figure 1), this correlation is not as strong as other authors have noted for less diverse language samples. The average %V/ΔC quotient of languages with simple syllable structure (1.52) is notably higher than that of languages with complex syllable structure (1.02). This suggests that a putative universal relationship between %V and ΔC is not confirmed, as the precise nature of the relationship between the two metrics differs according to syllable structure.

Figure 1: Languages plotted according to mean %V and ΔC values.



4.2. Vowel length

The mean %V, ΔC, and ΔV values obtained according to the presence or absence of contrastive vowel length are shown in Table 3. Mean values for %V and ΔC are quite similar for the two groups, while ΔV varies as a function of contrastive vowel length. Regression analysis confirms that contrastive vowel length only has a significant effect on ΔV (p<.05). Additionally, there is no interaction between syllable structure and contrastive vowel length.

Table 3: Mean %V, ΔC and ΔV values according to presence or absence of contrastive vowel length. ΔC and ΔV values measured in msec.

Vowel Length	%V	ΔC	ΔV	%V/ ΔC
Contrastive (N = 11)	54.4	46.0	56.8	1.18
Not Contrastive (N = 11)	53.2	47.6	49.8	1.12

Although not as strong as the relationship between %V and ΔC, a correlation exists between %V and ΔV (r =.301, p<.05) as well: more vocalic interval variation occurs with a higher proportion of vocalic intervals. While such a relationship seems intuitive enough, it has not been noted previously in less diverse language samples.

Although syllable complexity affects %V, and a strong relationship exists between %V and ΔV for both syllable complexity types, syllable structure surprisingly has no reliable effect on ΔV.

4.3. Vowel reduction

The mean %V, ΔC, and ΔV values obtained for languages that exhibit vowel reduction processes versus those that do not are shown in Table 4.

Table 4: Mean %V, ΔC and ΔV values according to presence or absence of vowel reduction. ΔC and ΔV values measured in msec.

Vowel Reduction	%V	ΔC	ΔV	%V/ ΔC
Reduction (N = 7)	53.1	50.8	55.9	1.05
No Reduction (N = 15)	54.1	44.9	52.1	1.20

The means show very little variation as a function of vowel reduction. Regression analysis confirms that vowel reduction has no significant effect on these measurements.

Table 5: Combined effect of syllable complexity, contrastive vowel length, and vowel reduction on metrics. ΔC and ΔV values measured in msec.

	Complex Syllable Structure	
	Vowel Reduction	**No Vowel Reduction**
Contrastive Vowel Length	**%V = 54.4** **ΔC = 50.1** **ΔV = 61.5** (N = 4)	**%V = 51.1** **ΔC = 49.4** **ΔV = 53.8** (N = 4)
No Contrastive Vowel Length	**%V = 51.5** **ΔC = 51.8** **ΔV = 48.5** (N = 3)	**%V = 51.8** **ΔC = 53.4** **ΔV = 55.0** (N = 4)

However, Table 5 shows the interaction between vowel reduction and contrastive vowel length for languages with complex syllable structure. The distribution of ΔV values in the table suggests that vowel reduction when coupled with contrastive vowel length results in an increase in the variability of vocalic intervals.

5. DISCUSSION

The results yielded by this study hold several interesting implications for the standard assumptions about what factors underlie the variation in the acoustic factors proposed as potential correlates of the rhythmic classification of languages.

The fact that %V shows limited (albeit significant) variation as a function of syllable complexity whereas ΔC is decidedly more variable suggests that the proportion of vocalic intervals for a given language is not a simple function of ΔC, the standard deviation in consonantal intervals, or vice-versa.

While both %V and ΔC broadly vary as a function of syllable complexity, the disparity between average %V/ΔC quotients for languages with complex syllable structure (1.02) and simple syllable structure (1.52) suggests that ΔC can vary independently of %V in a way that may be correlated with differences in syllable complexity across languages. Thus, the assumption that %V and ΔC collectively reflect syllable complexity in any straightforward way may be inaccurate.

The phonological factors reflected by %V as a metric, however, are not especially clear. Neither contrastive vowel length nor vowel reduction has a significant effect on %V. However, a correlation does exist between %V and ΔV. The fact that more vocalic variation relates to a higher proportion of vocalic intervals suggests that contrastive vowel length, and not vowel reduction, is affecting %V values, and that %V as a metric is not merely a proxy for ΔC.

While it is generally assumed that %V is reflective of vowel reduction (as in Ramus et al.'s data the lowest values for this measure are for English, Dutch and Portuguese — which all have notable vowel reduction), this is not the case cross-linguistically. Thus the traditional explanation for the correlation between %V and ΔC, namely the co-occurrence of heavy syllables and reduced vowels in languages with complex syllable structure, cannot account for the variation observed in this study.

An additional relevant finding is that contrastive vowel length has a significant effect on the variation of vocalic intervals. This has been the general assumption in the literature [8]. Also, languages with more complex syllable structure exhibit more variation in ΔV. Because in these data all languages with vowel reduction processes also have complex syllable structure, this finding suggests that reduction may have some marginal effect on ΔV values. It could also suggest, however, that either syllable structure somehow determines vocalic variation, or that factors other than contrastive vowel length or reduction, such as non-phonemic vowel lengthening or the presence of inherently long vowels (e.g. diphthongs), are affecting ΔV as well.

Finally, the results of this study suggest the possibility that the purportedly universal uniform relationship between %V and ΔC may not be cross-linguistically valid as a universal. While such a relationship seems to hold for languages with complex syllable structure, the same cannot be said as confidently for languages with simple syllable structure.

6. REFERENCES

[1] Boersma, P., Weenink, D. 2011. Praat: Doing phonetics by computer. *http://www.fon.hum.uva.nl/praat/*

[2] Cassandro, M., Collet, P., Duarte, D., Galves, A., Garcia, J. 2003. A universal linear relation among acoustic correlates of rhythm. Unpublished MS. *http://www.ime.usp.br/~tycho/participants/a_galves/linearity.pdf* Retrieved 3 March 2011.

[3] Dauer, R.M. 1983. Stress-timing and syllable-timing reanalyzed. *Journal of Phonetics* 11, 51-62.

[4] Easterday, S., Timm, J. 2010. *Beyond Stress-Timed and Syllable-Timed: A Look at the Rhythm Patterns of Languages of Papua New Guinea and the Pacific Northwest.* Paper presented at *The Ninth High Desert Linguistics Society Conference* Albuquerque, NM.

[5] Global Recordings Network. *http://globalrecordings.net/*

[6] Grabe, E., Low, E.L. 2003. Durational variability in speech and the rhythm class hypothesis. *Papers in Laboratory Phonology* 7, 515-546.

[7] Maddieson, I. 2008. Syllable structure. In Haspelmath, M., Dryer, M.S., Gil, D., Comrie, B. (eds.), *The World Atlas of Language Structures Online*. Munich: Max Planck Digital Library. Available online at *http://wals.info/feature/12.* Accessed on 2/3/2011.

[8] Ramus, F., Nespor, M., Mehler. J. 1999. Correlates of linguistic rhythm in the speech signal. *Cognition* 73, 265-292.

[9] Roach, P.J. 1982. On the distinction between 'stress-timed' and 'syllable-timed' languages. In Crystal, D. (ed.), *Linguistic Controversies*. London: Edward Arnold, 73-79.

[10] The Languages and Cultures of Northeast Eurasia. *http://www.ling-atlas.jp/index_en.html*