1. Introduction
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1 Introduction

What is rhythm?
Rhythm in music?
Rhythm in speech?
1 Introduction

Possible definition of rhythm:
Rhythm is the systematic organization of prominent and less prominent speech units in time.

Speech units:
e.g. syllables, vocalic intervals

Prominence:
higher fundamental frequency
higher duration
higher intensity
1 Introduction

Speech & Language rhythm

Speech rhythm
Rhythmical patterns in speech that are not language specific.

Language rhythm
Language specific rhythmical patterns of speech rhythm

Discussion since the 1950s is mainly about language rhythm.
2 Language Rhythm

Isochrony Hypothesis
Pike (1945)
Abercrombie (1967)

Two Rhythm Classes

stress timed rhythm
Languages showing patterns of equal duration between stressed (prominent) syllables.

(morse code rhythm)

e.g. English, Dutch, German

syllable timed rhythm
Syllables are of equal duration.

(machine gun rhythm)

e.g. French, Spanish, Italian
Abercrombie (1967): Language rhythm related to the physiology of speech production:

**chest pulses**: puffs of air to produce a syllable

**stress pulses**: reinforced chest pulse

**foot**: unit of a stress pulse and the following chest pulses

**stress-timed languages**:
- stress pulses are equally spaced – chest pulses are not
- no isochrony between feet measurable

**syllable-timed languages**:
- chest pulses are equally spaced – stress pulses are not
- no isochrony between syllable durations measurable
The nature of syllable & stress timing

**syllable timing:** (syllable isochrony = here: 11 equally timed syllables)

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1 2 3 4 5 6 7 8 9 10 11
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**stress timing:** (foot or interstress isochrony = here: 3 equally timed feet)

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1 2 3
```

- = prominent syllable
- = non-prominent syllable
2 Language Rhythm

Conclusion:

- production-level
  - stress pulses/chest pulses

- perception-level
  - prominence

- acoustic-level
  - f0
  - intensity
  - duration

rhythm
MAIN PROBLEM:
finding experimental evidence
i.e.:
finding acoustic correlates of language rhythm in the speech signal

since the late 1960s researchers have been trying that with more or less success...
... suggestions!?
Roach (1982) – hypotheses:
If isochrony-theory holds then...
(i) ...there is considerable variation in syllable length in a language spoken with stress-timed rhythm whereas in a language spoken with syllable-timed rhythm the syllables tend to be equal in length.
(ii) ...in syllable-timed languages stress pulses are unevenly spaced.
3 Early Rhythm Measurements

Roach (1982) – method:
syllable-timed languages
- French
- Telugu
- Yoruba

stress-timed languages:
- English
- Russian
- Arabic

(i) Calculate & compare variation of relative syllable duration
(ii) Calculate & compare variation of relative foot duration
3 Early Rhythm Measurements

Roach (1982) – results:

(i) Syllable variation is not significantly different for between stress-timed and syllable-timed languages.

(ii) High variability in foot variation for stress-timed languages (especially for English).
Problem:
Where is rhythm in the speech signal?

What level has so far been neglected in rhythm studies?
The perception of rhythm:

Benguerel and D‘Arcy (1986):
- Acoustically irregular sequences of syllables are rated as being regular

Beckman (1992):
- Stress-timing is a perceptual product more than an acoustic or production phenomenon.

O‘Connor (1965):
- Stress units are not produced regularly
- Irregularly produced stress units are perceived regularly
Conclusion:

At the beginning of the 1990s the discussion about rhythm classes stopped with the result:

- Rhythm cannot be measured in the speech signal.
- Rhythm is a mere perceptual phenomenon.
New idea already put forward in Roach (1982):

a.) stress-timed languages allow complex consonant clusters
   → higher variation or content of complex consonant clusters

b.) stress-timed languages allow vowel reduction
   → higher variation or content of vocalic intervals
4 Recent Rhythm Measurements

Ramus (1999):  
\( \Delta C \) = standard deviation of consonantal intervals  
\( \Delta V \) = standard deviation of vocalic intervals  
\( \%C \) = percentage of consonantal intervals  
\( \%V \) = percentage of vocalic intervals
4 Recent Rhythm Measurements

Ramus et al. (1999) findings

- Stress timed languages
- Syllable-timed languages

ΔC

%V
Grabe & Low (2002):
raw & normalized pairwise variability index

\( nPVI = \) normalized PVI for vocalic intervals
\( rPVI = \) raw PVI for consonantal intervals
4 Recent Rhythm Measurements

Grabe & Low (2002) findings

nPVI

rPVI

stress timed languages

syllable-timed languages
Problem:

Ramus (1999) and Grabe & Low (2002):

- only one speaker per language
- speech rate not well controlled

Idea:

Checking the measure on a large database at different speech rates.
Barry et al. (2003):
- $\Delta C$ & $\Delta V$ decrease with an increase in speech rate
- nPVI does not normalise for speech rate

Dellwo & Wagner (2003):
- $\Delta C$ decreases with an increase in speech rate
- $%V$ is constant over all speech rates
Diagram 1: Results for %V and ΔC under different intended speech rate conditions (s2, s1, no, f1, f2) for the languages English, French, and German.
Dellwo (forthcoming):

Decrease of $\Delta C$ and $\Delta V$ to be expected since shorter intervals in fast speech will cause lower standard deviation

p.t.o.
5 Rhythm & Speech Rate

**Slow speech**

- e.g.: 16 msec

- mean C

- ΔC

- ΔC

- e.g.: 7 msec

**Fast speech**

- e.g.: 9 msec

- mean C

- ΔC

- ΔC

- e.g.: 4 msec
5 Rhythm & Speech Rate

slow speech

mean C

ΔC     ΔC

varcoΔC = 43.8 %

fast speech

mean C

ΔC     ΔC

varcoΔC = 44.4 %
5 Rhythm & Speech Rate

Diagram 2: Results for %V and varcoΔC under different intended speech rate conditions (s2, s1, no, f1, f2) for the languages German, French, and English.

Dellwo (forthcoming) findings
6 Conclusion

1.) The major questions in language rhythm still remain untouched: Perceptual evidence for stress- and syllable-timing

2.) We seem to be still far from a satisfying description of rhythm.
Question for discussion:

Why do we need to study rhythm at all?


