Rhythm

An interactive introduction

Dafydd Gibbon

U Bielefeld

Ak-Phon 2005-07-13
Overview

- Definitions and examples of rhythm
- Emergent Rhythm Theory (ERT)
- Timing factors in linguistics and phonetics
  - Levels of patterning and isochrony
- Phonological rhythm theories
  - Metrical Phonology, Prosodic Hierarchy
- Phonetic rhythm theories
  - Patterns: Pike, Abercrombie, Jassem
  - Global isochrony: Isard, Roach, ...
  - Global pattern ratio: Ramus, ...
  - Local linear: Low & Grabe
- A new strategy
  - Measuring rhythm types
  - Inducing hierarchical temporal patterns
Presentation strategy

- Lecture: introduction to
  - basic concepts
  - approaches
- Discussion: intuitive explicanda for “rhythm”
- Method practice:
  - temporal annotation (with annotation software)
    - selection of units – C/V clusters, syllables, feet
  - manual analysis of annotation (with spreadsheet)
    - mean durations
    - variance & standard deviation of durations
    - Low & Grabe PVI (pairwise variability index)
    - Gibbon TPA (temporal periodicity analysis)
Rhythm definitions & examples

Etymology: Middle French & Latin; Middle French rhythm, from Latin rhythmus, from Greek rhythmos, probably from rhein to flow -- more at STREAM

1 a : an ordered recurrent alternation of strong and weak elements in the flow of sound and silence in speech b : a particular example or form of rhythm <iambic rhythm>

2 a : the aspect of music comprising all the elements (as accent, meter, and tempo) that relate to forward movement b : a characteristic rhythmic pattern <rumba rhythm>; also : 1METER 2 c : the group of instruments in a band supplying the rhythm -- called also rhythm section

3 a : movement or fluctuation marked by the regular recurrence or natural flow of related elements b : the repetition in a literary work of phrase, incident, character type, or symbol

4 : a regularly recurrent quantitative change in a variable biological process <a circadian rhythm> -- compare BIORHYTHM

5 : the effect created by the elements in a play, movie, or novel that relate to the temporal development of the action
Rhythm definitions & examples

*Rhythm* in general...

Rhythms in particular:
- Acoustic
- Visual
- Patterns:
  - trochaic
  - iambic
  - dactylic
  - anapaestic
- Complex:
  - beat
  - heterodyne
  - moiré
What makes rhythm?

• Basic position:
  – rhythm is *emergent* i.e. a function of many different factors, e.g.
    • cognitive expectations
    • “biological clocks”
    • Temporal properties of prosodic hierarchies - cf. Tillmann's
      – A prosody: timing level of phonemes
      – B prosody: timing level of syllables, words
      – C prosody: timing level of phrases
    • Articulatory constraints (elastic tissues, weight of bones, ...)
    • Acoustic patterns
    • Integrative powers of the ear and hearing

• Pragmatic position:
  – this is all too complicated
  – let's concentrate first on what we can measure, for heuristic reasons (without rejecting other dimensions)
Emergent complex rhythms (1)

Rhythm 1:

Rhythm 2:

Rhythm 3:
Emergent complex rhythms (2)

Rhythm 1:

Rhythm 2:

Rhythm 3:
Timing factors in speech

● Phrase:
  – Speech tempo
  – Parenthetic speech
  – Emphatic accent
  – Focal / contrastive accent
  – Phrasal accent (realisation of sentence stress)

● Word:
  – Accent (realisation of word stress)
  – Word stress
  – Foot: speech tempo
  – Syllable: strong/long – weak/short syllables
  – C & V contrastive phoneme durations
  – Allophonic duration variation (e.g. Eng. V[+st])
Phonological rhythm theories

- Syllable vs. Stress/Foot timing
  - Pike
  - Abercrombie

- Stratified hierarchies:
  - Jassem
  - Prosodic Hierarchies
    - Selkirk, Hayes
    - Campbell

- General hierarchies:
  - Metrical Phonology
Phonetic rhythm theories

• Global:
  – variance, standard deviation (isochrony):
    • Isard
    • Roach
  – peak-trough ratio:
    • Ramus
  – Periodicity Analysis
    • Gibbon

• Local:
  – peak-trough alternation ratio:
    • Low, Grabe & Nolan (PVI)
    • Gibbon & Gut (RR)
    • Gibbon (Time Tree Induction)

• Dynamic:
  – Barbosa, Cummins, Wachsmuth, ...
Practical: annotation & analysis

- Choose a short speech file
- Annotate the following tiers with Praat:
  - Phonemes
  - Syllable
  - Feet
- The following can be done automatically, but...
  - Enter the time-stamps for each tier into separate worksheets of a spreadsheet program (OpenOffice Calc, Excel)
  - For each tier:
    - calculate average length (AL) of units
    - calculate standard deviation (SD) of units
    - normalise by dividing SD/AL (0 = isochrony)
### Average length and speech rate

<table>
<thead>
<tr>
<th>Phon</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
</tr>
<tr>
<td>170</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>63</td>
</tr>
<tr>
<td>110</td>
</tr>
<tr>
<td>140</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Syll</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>123</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>120</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>178,6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>473</td>
</tr>
<tr>
<td>420</td>
</tr>
<tr>
<td>446,5</td>
</tr>
</tbody>
</table>

**AL:** Average Length (in msec)  
**Rate:** 1000 / AL (in sec)  
**SD:** Standard Deviation
## NDI: an isochrony measure

<table>
<thead>
<tr>
<th>Phon</th>
<th>Syll</th>
<th>Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>250</td>
<td>473</td>
</tr>
<tr>
<td>170</td>
<td>100</td>
<td>420</td>
</tr>
<tr>
<td>40</td>
<td>123</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| AL   | 84.3 | 178.6 | 446.5 |
| SD   | 42.3 | 90.19 | 37.48 |
| NDI  | 0.5  | 0.51  | 0.08  |

SD: Standard Deviation
AL: Average Length
NDI = SD/AL: Normalised Deviation Index (>= 0)
  Perfect isochrony: NDI = 0
PVI: a binary alternation measure

| Phon | Δdur | |Δdur| | AVG | |Δdur|/AVG | Syll | Δdur | |Δdur| | AVG | |Δdur|/AVG | Foot | Δdur | |Δdur| | AVG | |Δdur|/AVG |
|------|------|-----|--------|------|------|-----|--------|------|------|-----|--------|------|-----|--------|------|-----|--------|------|-----|--------|------|-----|
| 80,00 | -90,00 | 90,00 | 125,00 | 0,72 | 250,00 | 150,00 | 150,00 | 175,00 | 0,86 | 473,00 | 53,00 | 53,00 | 446,50 | 0,12 |
| 170,00 | 130,00 | 130,00 | 105,00 | 1,24 | 100,00 | -23,00 | 23,00 | 111,50 | 0,21 | 420,00 | 420,00 | 420,00 | 420,00 | 1,00 |
| 40,00 | -20,00 | 20,00 | 50,00 | 0,40 | 123,00 | -177,00 | 177,00 | 211,50 | 0,84 |
| 60,00 | 0,00 | 0,00 | 60,00 | 0,00 | 300,00 | 180,00 | 180,00 | 210,00 | 0,86 |
| 60,00 | -3,00 | 3,00 | 61,50 | 0,05 | 120,00 |
| 63,00 | -47,00 | 47,00 | 86,50 | 0,54 |
| 110,00 | -30,00 | 30,00 | 125,00 | 0,24 |
| 140,00 | 90,00 | 90,00 | 95,00 | 0,95 |
| 50,00 | -20,00 | 20,00 | 60,00 | 0,33 |
| 70,00 |

**AVG**

| Phon | Δdur | |Δdur| | AVG | |Δdur|/AVG | Syll | Δdur | |Δdur| | AVG | |Δdur|/AVG | Foot | Δdur | |Δdur| | AVG | |Δdur|/AVG |
|------|------|-----|--------|------|------|-----|--------|------|------|-----|--------|------|-----|--------|------|-----|--------|------|-----|
| 80,00 | -90,00 | 90,00 | 125,00 | 0,72 | 250,00 | 150,00 | 150,00 | 175,00 | 0,86 | 473,00 | 53,00 | 53,00 | 446,50 | 0,12 |
| 170,00 | 130,00 | 130,00 | 105,00 | 1,24 | 100,00 | -23,00 | 23,00 | 111,50 | 0,21 | 420,00 | 420,00 | 420,00 | 420,00 | 1,00 |
| 40,00 | -20,00 | 20,00 | 50,00 | 0,40 | 123,00 | -177,00 | 177,00 | 211,50 | 0,84 |
| 60,00 | 0,00 | 0,00 | 60,00 | 0,00 | 300,00 | 180,00 | 180,00 | 210,00 | 0,86 |
| 60,00 | -3,00 | 3,00 | 61,50 | 0,05 | 120,00 |
| 63,00 | -47,00 | 47,00 | 86,50 | 0,54 |
| 110,00 | -30,00 | 30,00 | 125,00 | 0,24 |
| 140,00 | 90,00 | 90,00 | 95,00 | 0,95 |
| 50,00 | -20,00 | 20,00 | 60,00 | 0,33 |
| 70,00 |

**AVG**

- 0,50
- 0,69
- 0,56

**PVI**

- 49,68
- 68,94
- 55,94

**PVI:**

\[
100 \times \frac{\text{AVERAGE}(|\text{diff}_{i} - \text{diff}_{i+1}|)}{\text{AVERAGE}(\text{diff}_{i}, \text{diff}_{i+1})}
\]
Perspective...

- Implementation and further development dynamic approaches:
  - Barbosa
  - Cummins
  - Wachsmuth

- Development of rhythm typology measures:
  - unary (cf. syllable timing)
  - binary: iambic, trochaic
  - ternary: dactylic, anapaestic
  - other ...

- Relation of phonetic patterns to patterns of:
  - phonology
  - morphology
  - phrasal syntax
  - discourse