Speech rhythm and f0 patterns in Bengali:
A study of infant-directed speech

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Research questions

Infant-directed speech (IDS) involves various phonetic changes, including:
Expansion of the vowelspace [A&K96, B&a02]
Stop VOT manipulation [S&L99, S01]
Overall pitch increase [G&K99, M92, F&a89]

Infants are sensitive to patterns in speech rhythm [M&a97] **and f0** [R02]...
...so how do those patterns change in IDS?

We consider the following **in Bengali**:

1. Speech rhythm
Regular alternation of C&V = "syllable-timed"
Irregular alternation of C&V = "stress-timed"
(These are traditional terms; more of a continuum than a dichotomy [R&a99])

2. f0 patterns (intonation)
Regular alternation of L&H
We pursue a phonological analysis...
...not a phonetic analysis (well-established)

Bengali phonology

From [K08], [Kta]:

Syllabic structure and stress pattern

- Native words have **(C)V(C) syllables only**
- Clusters only in Sanskritic/borrowed words
- **No V length contrast**
- C length contrasts only intervocalically
- Weak stress, consistently word-initial

→ **This high regularity in C- and V-intervals** suggests a rhythmic system similar to so-called **"syllable-timed"** languages

Intonational structure

- Resembles French [J&F00] and Farsi [E&B07]
- Typically, each content word bears a pitch accent (T*) on the stressed/initial syllable, and an accentual phrase (AP) boundary tone (Ta) on the right edge.
- Default APs bear rising pitch: L*...Ha
- So, **sentence = sequence of repeated rises**
- APs group into intermediate phrases (ip)
- ips group into intonation phrases (IP)

→ **This repetition of a word-sized pitch contour** suggests an intonational system with strong **"macrorhythm"** [J10]

Methods: recording

Speakers

- **10 Bengali speakers**: 5 M, 5 F
- Parents of young children

Speech materials

- Bengali translation of *North Wind and the Sun*
  - Also used in other rhythm studies [G&L02]
  - Suitable for both typical lab speech and IDS

Recording

- Audio recorded in quiet room
- **Three reps** for each **speech style condition**:
  - **Read speech**: "Read at a comfortable pace"
  - Simulated **infant-directed speech (IDS)**: "Read as if speaking to an infant (~4 mos)"; participants given stuffed toys

Methods: rhythm analysis

Labeling

- Recordings were labeled using Praat text grids:
  - **Phonemic** transcription
  - **Syllable** boundaries
  - **C & V** intervals
  - **Voiced & Voiceless** intervals (automated)

Analysis

- Segmental rhythm metrics
  - **%V** [R&a99]: % of speech that is vocalic
  - **ΔC** [R&a99]: std. deviation of C-intervals
  - **C-rPVI** & **V-nPVI** [G&L02]: pairwise comparisons of C- & V-intervals, respectively
- **RM 1-way ANOVAs** compared these metrics **by speech style**: read vs. IDS

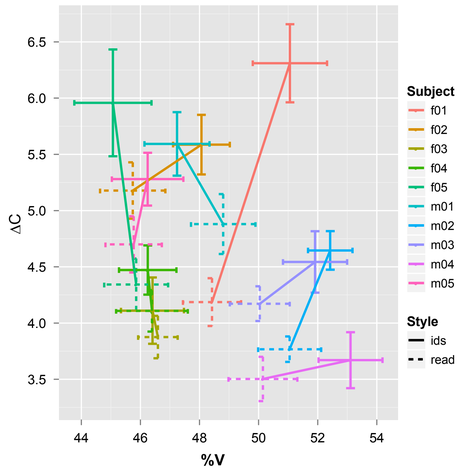
Results: rhythm analysis

Read speech

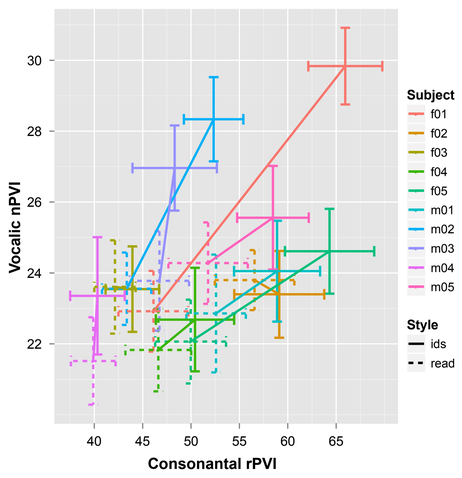
- **%V**: *mixed results*
  - between "**syll-timed**" Sp., It., Fr., Cat. and "**mora-timed**" Jpn., farthest from "stress-timed" Eng., Dut. following [R99]
  - within "**stress-timed**" range following [A09]
- **ΔC, C-rPVI**: within "**syll-timed**" range
- **V-nPVI**: below range, closest to "**syll-timed**"

Modifications in IDS

- **%V**: *not significant*
- **ΔC, C-rPVI**: **higher**, towards "**stress-timed**"
- **V-nPVI**: **higher**, towards "**stress-timed**", but still below overall range



Read vs. IDS by subjects in [R&a99] 2-D rhythm metric space



Read vs. IDS by subjects in [G&L02] 2-D rhythm metric space

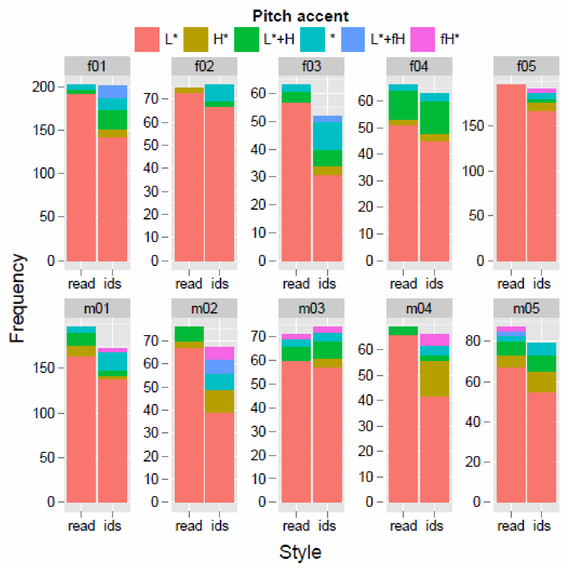
Methods: intonational analysis

Labeling
- 1st author annotated text grids in **B-ToBI** [Kta]
- Based on intonational phonological model [K08] summarized in left column

Analysis
- B-ToBI labels analyzed by automated scripts.

Results: intonational analysis

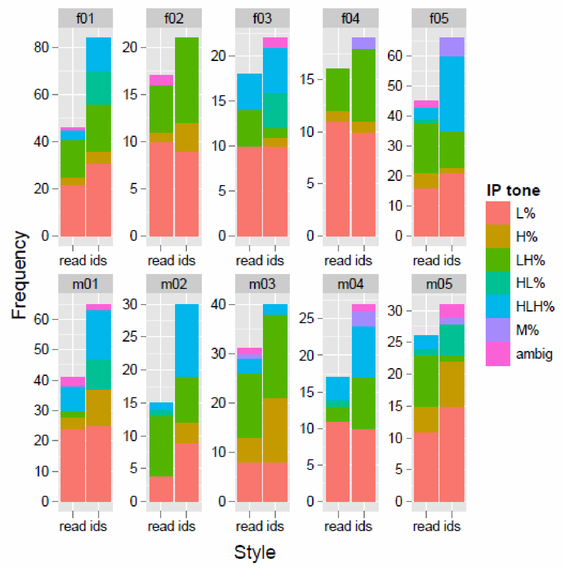
Pitch accents
- No change in number of PAs in IDS, but...
- **Fewer default PAs** (L*)
- Coincides with **increase in number** of:
  - **Nuclear PAs**: H* (new info.), L*+H (emph.)
  - **Focus PAs**: fH* (surprise), L*+fH (wh/corr.)
  - **Post-focal PAs**: * (prominence w/out tone)



Distribution of pitch accents in both speech styles, for PA types of at least 2% relative frequency within a speaker and style.

Prosodic phrases
- Increase in number of IPs in IDS
- Increase in use of H-initial IP tones in IDS:
  - **HLH%**, conveying **continuation**
  - **HL%**, conveying **topicalization**
  - **H%**, conveying **either contin. or topic.**

- Many used HLH% in place of LH% to convey continuation, adopting a **more complex** contour



Distribution of IP boundary tones in both speech styles, for types of at least 2% relative frequency within a speaker and style.

Discussion

Bengali segmental rhythm and intonation reveal a high degree of regularity
- Bengali rhythm patterns with **"syllable-timed" lgs**., esp. along ΔC & C-rPVI metrics
- In intonational structure, Bengali has a **repeating pitch pattern** of rising APs

In IDS, segmental rhythm and intonational patterns become increasingly irregular
- Increases in ΔC, C-rPVI, V-nPVI
- Increase in use of non-default pitch accents
- Increase in number of IPs ending in various boundary tones, many with complex contours

How can we reconcile this finding with claims that **speech rhythm and f0 patterns are important for word boundary recognition** [C&a86, K&C09, W&a]?

Wouldn't disruption in regularity **reduce an infant's ability to recognize words**?

Three possible explanations:
1. Infants are exposed to **non-IDS styles**
2. The goal of IDS is to **engage the infant**, and regularity will bore him/her [S&a82]
3. The goal of IDS is to **highlight particular words** beyond normal intonation [B&A94]

Explanations 2-3 are consistent with the **decrease in rhythmic regularity** and the **increase in use of marked tonal patterns**

In Bengali, **IDS** can be seen as a **speech style** used to **engage the listener** and/or **draw attention to certain words** through **reduction in rhythmic and intonational regularity**

Ongoing and future research

- **Regularity in acoustic f0 variation** and its connection to intonational phonological tones
- **Machine classification**: are units acoustically identifiable without lg.-specific training [L&a11]?
- **Cross-linguistic comparison**: other "syll.-timed" lgs., "stress-timed" lgs., tone lgs., etc.

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