Implicit rhythm affects parsing decisions in reading

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Experimental Studies on Intonation – Phonetic, Phonological and Psycholinguistic Aspects of Sentence Prosody
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The German does not read aloud, does not read for the ear, but merely with his eyes: he has put his ears away in the drawer. (F. Nietzsche, Beyond Good and Evil)
• What is the role of the ear in reading?

More specifically:
• What is the role of prosodic-phonological processing in reading
• How does prosodic-phonological processing affect sentence comprehension in reading?
Structure of the talk

Background
• Reading and phonological recoding in reading
• (implicit) prosody and sentence comprehension
• Rhythm in sentence processing

Experiments
• Reading aloud
• Silent reading

Discussion
Background I: Phonological recoding in reading

Koriat et al. 2002 (and everyday experience):

- Reading aloud involves both sentence comprehension and production.
- Readers generate sentence prosody online (without advance preparation) when reading aloud.
- Reading prosody reflects syntactic structure of the written string.

The fat cat # with the gray stripes # ran quickly to the little kitten…
The role of prosody in reading

• Readers generate prosody in compliance with the words/ sentences they read.
• In auditory sentence comprehension, prosody has the potential to disambiguate syntactic structures or to highlight prominent material (e.g. contrast).
• The written string lacks explicit prosodic information.

→ Q1: How is prosody generated?
→ Q2: Does the reading prosody merely reflect the reader‘s syntactic analysis of the text or does it contribute to the interpretation process?
The role of prosody in reading

“Readers as opposed to listeners do not get prosodic information as part of the input; therefore they cannot use it to reconstruct structure.” (Kreiner 2005)

“[…] readers must generate the natural prosody of the sentence on the basis of various structural (i.e. *lexical / syntactic*) cues.” (Koriat et al. 2002)

“[…] prosody plays an important role as a means of representing the output of the early structural analysis.” (Koriat et al. 2002)

Syntax precedes prosody. Prosody reflects syntax.
Standard model for prosody generation in reading

graphemic input → word recognition → lex-synt. features → structure building → (implicit) prosody ⊃ phonol. recoding
The role of prosody in reading

“Prosody is mentally projected by readers onto the written or printed word string. And - the crucial point - it is then treated as if it were part of the input, so it can affect syntactic ambiguity resolution in the same way as overt prosody in speech does.” (Fodor 2002)

Prosody contributes to syntactic structure building in reading.
Prosody in written sentence processing – Problem (Fodor 2002)

An apparent paradox:

• “Prosody in reading must be projected on the basis of the lexical string and the syntactic structure assigned to it, so how could that projected prosody influence the assignment of syntactic structure to the lexical string?”

• “Syntactic analysis and prosody assignment can be interleaved, with prosodic processing following along in the wake of lowlevel syntactic processing, and feeding later syntactic decisions.”
Prosody in written sentence processing – Problem (Fodor 2002)

• “If the prosody in reading is derived from the lexical/syntactic facts, it must be redundant, in a strict sense.”

• “Unlike the prosodic contour of a spoken sentence, it cannot in principle contribute any additional information.”

• “Though phonological encoding may be an efficient way to REPRESENT sentence structure, it cannot supply any facts to DISAMBIGUATE sentence structure. Thus, implicit (internal, silent) prosody may exist, but it couldn’t in principle make any difference to sentence-level processing.”
Prosody in written sentence processing

Possible objection:
Prosody might be projected onto the string on the basis of sub-lexical information. Syllables and the prosodic structure derived from the syllabic structure (such as stress information) might feed the parsing process. This kind of (implicit) prosody would not be redundant in the sense mentioned before.

How could that happen?
Implicit prosody and sentence processing

Evidence for early activation of syllable and stress information in (silent) reading – even before the word is in the visual focus (Ashby & Rayner, 2004; Ashby & Clifton, 2005; Ashby, 2006; Ashby & Martin, 2007)

Sublexical prosodic-phonological information is routinely activated during the reading process.

- But how could it contribute to sentence processing?

Linguistic Rhythm
Rhythm in sentence processing

- Speakers prefer an alternation of strong and weak syllables. The concatenation of words in speech production involves rhythmic adjustments (in spontaneous speech and reading aloud)
  
  * thirteenth men → thirteeen mén

- Given the choice, speakers use syntactic configurations without stress clashes. Evidence from corpus analyses (Anttila, Adams & Speriosu 2008)

  * I gave him the book (94.3% of realizations with pron. goal)
  * I gave Jim the book (26.6% of realizations with lexical goal)
Rhythm in sentence processing

Speakers alter syntactic structure to optimize rhythmic structure

- Sentence repetition experiment (U. Imhof 2008, Diploma thesis)
  ...dass Tim einschlafen hat wollen
  ... *that Tim fall-asleep AUX want*
  
  \[\rightarrow\]
  ...dass Tim hat einschlafen wollen
  ... *that Tim AUX fall-asleep want*

Interplay of rhythm and syntax. Stress clashes are avoided, either by reordering of constituents or rhythmic adjustments.

\[\rightarrow\] Clashes are prosodically suboptimal and cognitively costly.
Experiment

Research question:

Does sub-lexical prosody (syllables, rhythm) inform the parsing process and thus contribute to structure building in reading?
Syntactic ambiguity with prosodic involvement: “nicht mehr”- ambiguity

1) …dass Tina nicht mehr geraucht hat, seit sie im Krankenhaus war. …that Tina has not smoked anymore since she was in hospital.

2) …dass Tina nicht mehr geraucht hat, als ihre Mitschüler. …that Tina has not smoked more than her classmates

• “mehr” is either a temporal adverbial (together with “nicht”) (1) or a comparative adverb (2).
• In a phonological representation, (2) but not (1) requires accent on “mehr”.
Experiment I

Experiment:
Examination of “nicht-mehr”- ambiguity in different prosodic environments (reading aloud).

Hypothesis:
Avoidance of stress clash can influence parsing decisions.

2x2 design:
factor “ambiguity” (comparative vs. temporal adverb) and
factor “prosody” (initial stress vs. medial stress on following verb)
Experiment I

feststellen (to determine, to ascertain)
erfahren (to find out)

a) ...weil man nicht mehr feststellen konnte, wer der Täter war.
   because one couldn’t find out anymore, who the culprit was.
b) ...weil man nicht mehr erfahren konnte, wer der Täter war.
   because one couldn’t find out anymore, who the culprit was.
c) ...weil man nicht MEHR feststellen konnte, als die Tatzeit.
   because one couldn’t find out more, than the date of the crime.
d) weil man nicht MEHR erfahren konnte, als die Tatzeit.
   because one couldn’t find out more, than the date of the crime.
Experiment I: Predictions

a) …, weil man nicht mehr feststellen konnte, \textit{wer der Täter war.}
   \textit{because one couldn't find out anymore, who the culprit was.}

b) …, weil man nicht mehr erfahren konnte, \textit{wer der Täter war.}
   \textit{because one couldn't find out anymore, who the culprit was.}

c) …, weil man nicht MEHR feststellen konnte, \textit{als die Tatzeit.}
   \textit{because one couldn't find out more, than the date of the crime.}

d) …, weil man nicht MEHR erfahren konnte, \textit{als die Tatzeit.}
   \textit{because one couldn't find out more, than the date of the crime.}

Prosodic effect: (c) involves a stress clash and should be more difficult than (d)

$\rightarrow$ stress clash in (c) violates rhythmic wellformedness conditions and is consequently avoided, e.g. by leaving “mehr” unaccented.

$\rightarrow$ Need for re-analysis at disambiguating region in (c).
**Experiment I: unprepared reading aloud**

<table>
<thead>
<tr>
<th>Peter</th>
<th>Peter denkt, dass man nicht mehr ermitteln</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000 ms</td>
<td></td>
</tr>
</tbody>
</table>
Experiment I: Procedure and data analysis

Procedure
• 24 participants read 24 sentences in 4 conditions from screen without preparation = 576 experimental sentences

Data analysis
• 63 sentences (11%) discarded because of slips of the tongue or hesitations.
• Other sentences were cut before disambiguating region and judged for accentuation of “mehr“.
Results

- Across conditions “mehr” was judged as accented in 23.6% of cases.
- “Mehr” was accented less often when followed by a verb with initial stress ($z=-2.61$, $p<0.01$).
- “Mehr” was accented less often in sentences with comparative disambiguation ($z=-1.977$, $p=0.048$).
- Interaction of rhythmic environment and disambiguation non-significant.

*Inter-rater agreement: 96%*
Experiment I: Discussion

- Unaccented *mehr* is preferred over accented *mehr*.
- Although stress pattern of the verb is not explicitly encoded in the written string, it has a significant effect on realizations of accent on *mehr*. Readers avoid prosodic adjustments in the face of a possible clash by leaving *mehr* unaccented.

? Does the realization of stress on *mehr* merely reflect prosodic optimization, or does it involve a syntactic commitment?

➔ Pause duration at disambiguating region
Comparison of pause duration in correct versus incorrect continuations

<table>
<thead>
<tr>
<th></th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>correctness</td>
<td>-5.44</td>
</tr>
<tr>
<td>accent on MEHR</td>
<td>-1.28</td>
</tr>
<tr>
<td>disambiguation</td>
<td>1.86</td>
</tr>
</tbody>
</table>

..., weil man nicht mehr feststellen konnte, als die Tatzeit...
..., because one couldn’t find out anymore than the time...
..., weil man nicht MEHR feststellen konnte, wer der Täter...
..., because one couldn’t find out more who the culprit...
Experiment I: Discussion (II)

• The data on pause duration at the disambiguating region reveal a slow-down that points to syntactic reanalysis (garden path effect) in cases of incorrect realizations of *mehr*.

→ (de-)accenting *mehr* is not a purely prosodic optimization process…

…but involves the computation of the relevant syntactic features (comparative vs. temporal adverb)
Experiment I: Discussion (II)

→(de-)accenting *mehr* is not a purely prosodic optimization process…
…but involves the computation of the relevant syntactic features (comparative vs. temporal adverb)

Rhythmic preferences (stress clash avoidance) affect the realizations of accent and – at the same time - parsing decisions in reading aloud.
Experiment II

The German does not read **aloud**, [...] but merely with his eyes.

What is the role of (implicit) rhythm in **silent** reading?
Experiment II

Eye-tracking experiment

*Linking assumption:*

ease / difficulty of written sentence processing is reflected in eye movement behaviour:

reading times (first pass, re-reading, total reading time) and regression probabilities increase with processing difficulty.
Experiment II

Material

a) …weil man nicht mehr feststellen konnte, wer der Täter war.  
because one couldn’t find out anymore, who the culprit was.
b) …weil man nicht mehr erfahren konnte, wer der Täter war.  
because one couldn’t find out anymore, who the culprit was.
c) …weil man nicht MEHR feststellen konnte, als die Tatzeit.  
because one couldn’t find out more, than the date of the crime.
d) weil man nicht MEHR erfahren konnte, als die Tatzeit.  
because one couldn’t find out more, than the date of the crime.
Experiment II - Predictions

Stress clash avoidance should lead to reading difficulties in condition (c):
Readers will prefer the unaccented, temporal interpretation of *mehr* when it is followed by a verb with initial stress

→ longer reading times and higher regression rates when disambiguating region requires comparative reading.
Experiment II

a) ...because one couldn’t find out anymore, who the culprit was.

b) ...because one couldn’t find out anymore, who the culprit was.

c) ...because one couldn’t find out more, than the date of the crime.

d) ...because one couldn’t find out more, than the date of the crime.

→ Interaction between verb type and disambiguation

Measurements taken on first three words of disambiguating clause
Experiment II - Results

- First Pass Reading Time
- First Pass Regression Probability
- Re-Reading Time
- Total Fixation Time
Experiment II - Results

Predicted interaction is not significant in any of the dependent measures.

However, the difference between conditions c (clash) and d (no clash) is significant w.r.t. regression probability.

Problem: Disambiguating regions differ.

→ Need for a replication!!
Experiment II - Discussion

• Significant difference between conditions c (clash) and d (no clash) suggest the involvement of implicit linguistic rhythm in written sentence comprehension.

• As in reading aloud, readers prefer syntactic parses that do not imply stress clash configurations.
General discussion

Reading involves the syntactic analysis of the written string and the computation of its (implicit) linguistic rhythm. These processes interact with each other:

The parser avoids syntactic analyses that involve suboptimal prosodic representations. The parser uses rhythmic information to make syntactic decisions.
Extended model for prosody generation in reading

- Graphemic input
  - Word recognition
    - Lex-synt. features
      - Structure building
        - Rhythmic structure (local prosodic representation)
          - Phonol. recoding
            - Global prosodic representation
The German does not read aloud, does not read for the ear, but merely with his eyes: he has put his ears away in the drawer. (F. Nietzsche, Beyond Good and Evil)

According to Nietzsche, the ear, a.k.a. the phonological system is irrelevant during reading.

Present experiments:
The phonological system is routinely activated and used for making syntactic predictions in written sentence comprehension

The German doesn’t put his ears away in the drawer, neither when reading silently nor when reading aloud.
Thank you!

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References


Fodor, J. (2002). Psycholinguistics cannot escape prosody. Speech Prosody, Aix-en-Provence, France

