

# Linguistic Rhythm affects incremental sentence processing in reading

Phonologie-Kolloquium 24. April 2008

Gerrit Kentner

Meines Weinbergs Hyazinthen,  
welche Muskatduft verhauchen,  
haben ohne Zweifel Wurzeln,  
die bis in den Hades tauchen.

F.G. Jünger

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F.G. Jünger

→ **trochaic tetrameter**

*Peter, Peter, pumpkin eater...*

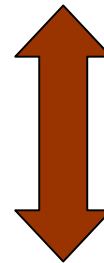
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Poem:

x -- x -- x -- x --

welche **Muskatduft** verhauchen,



Citation form:

**MusKATduft**

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# Background

- Rhythm in speech production
- Reading aloud and phonological recoding in reading
- (implicit) prosody in sentence processing

# Rhythm in speech production

- Speakers prefer an alternation of strong and weak syllables (also in prose, spontaneous speech, reading aloud).
- The concatenation of words in speech production involves rhythmic adjustments.
- Speakers avoid stress clashes by stress shift or de-stressing (Selkirk 1984, Hayes 1995 etc.).
  - \* thirtéen men → thirteen mén
- Speakers alter syntactic structure to optimize rhythmic structure (U. Imhof 2008, Diplomarbeit)
- Sentence repetition experiment
  - ...dass Tim einschlafen hat müssen
  - ...dass Tim hat einschlafen müssen

# 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.

# Implicit Prosody

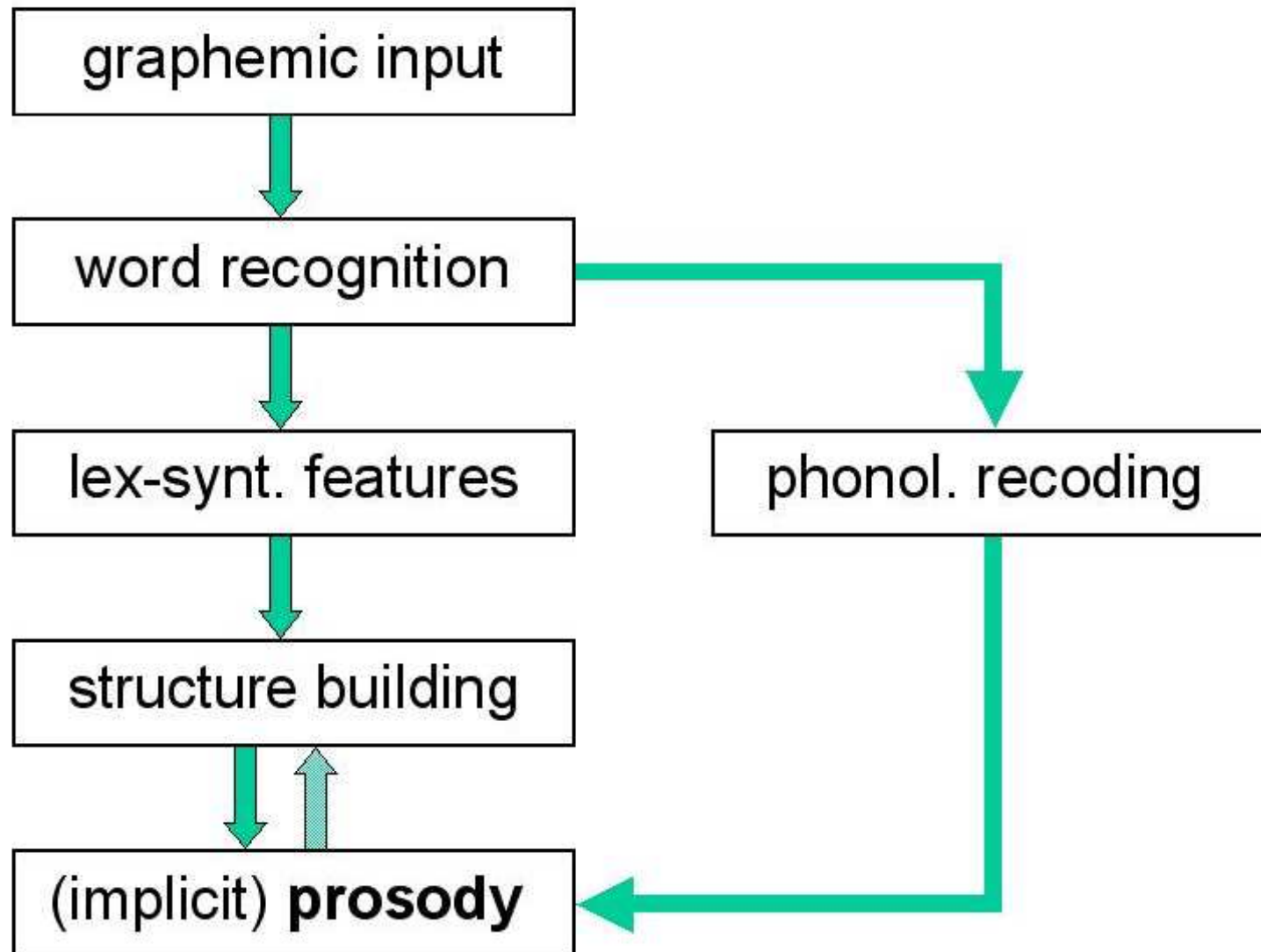
While reading, readers perceive an “inner voice“, that is they generate prosody in compliance with the words/sentences they read.

In auditory sentence comprehension, prosody is used to disambiguate syntactic structures or to highlight prominent material (e.g. contrastive stress).

The written string lacks explicit prosodic information.

Does the prosody generated during the reading process contribute to the interpretation process or does it merely reflect the reader’s analysis of the text?

## Standard model for prosody generation in reading



# Implicit Prosody in sentence processing – Problem (Fodor 2002)

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.

# Implicit Prosody in sentence processing – Problem (Fodor 2002)

Deeper problem:

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." (Fodor, 2002)

# Implicit Prosody in sentence processing

**Possible objection:** Prosody might be projected onto the string on the basis of syllables. The syllabic structure and the rhythm which is induced by the alternation of strong and weak syllables might feed the parsing process. This kind of implicit prosody would not be redundant in the sense mentioned before. It is not based on the lexical/syntactic facts but this information is sublexical or supralexic.

Evidence for activation of syllable and stress information in silent reading:

- Ashby & Clifton (2005)
- Ashby & Rayner (2004), Ashby (2006)

# Implicit prosody

Stress information in silent reading is psychologically real.

Ashby & Clifton (2005):

Reading times are longer for words with 2 stress positions compared to words with 1 stress position\*.

Poverty is the most *significant / fundamental* problem in our society today.

The newspapers publicised the *incompetence / exploitation* of the workers

\* Words matched for frequency and length

## Ashby & Rayner (2004), Ashby (2006)

Evidence for encoding of syllable information in silent reading:

Longer reading times for words for which the graphemic presentation in parafovea does not match syllable structure:

Parafoveal preview experiment:

Preview (match): Terry lost her po\_zvzvzv at the company

Preview (mismatch): Terry lost her pos\_vzvzv at the company

Target: Terry lost her position at the company

# Implicit prosody and sentence processing

Prosodic-phonological information in silent reading is psychologically real.

But does it contribute to sentence processing?

# Implicit prosody and sentence processing

Syntactic ambiguity with prosodic involvement:

*“nicht mehr”- Ambiguity*

a) ...dass Tina nicht mehr geraucht hat, seit sie im Krankenhaus war.

*...that Tina has not smoked anymore since she was in hospital.*

b) ...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”) (a) or a comparative adverb (b).
- In a phonological representation, (b) but not (a) requires stress on “mehr”.
- (b) induces garden path effect (Bader 1996).

# Experiment I

Experiment:

Examination of “nicht-mehr”- ambiguity in different prosodic environments.

Hypothesis:

Processing costs for stress clash can influence parsing decisions.

2x2 design:

factor “reading” (comparative vs. temporal adverb) and  
factor “prosody” (initial stress vs. medial stress on  
following verb)

# Experiment I

X . .

feststellen (*to determine, to ascertain*)

. X .

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.*

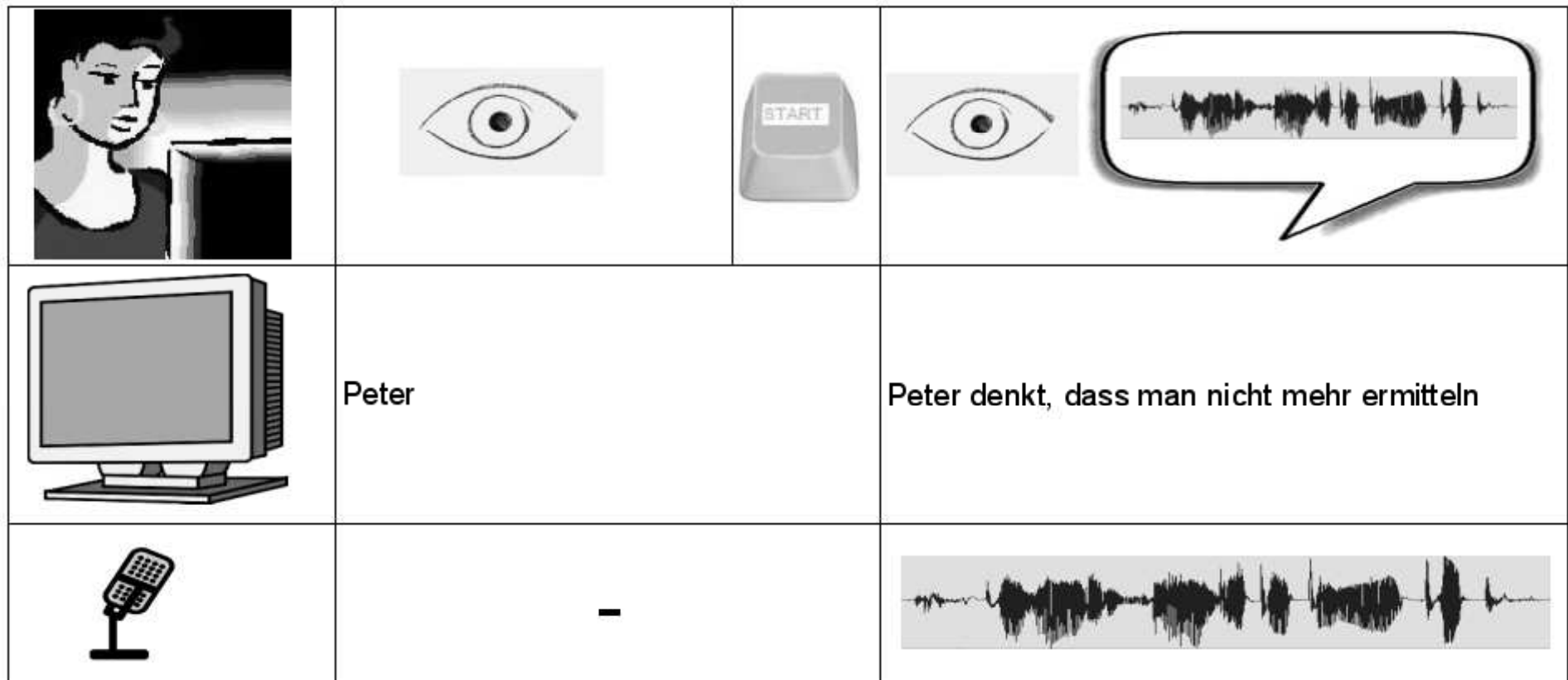
# Experiment I: Predictions

- a) ..., weil man nicht mehr feststellen konnte, 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.*

Effect of syntax: (c)+(d) are more difficult than (a)+(b)  
(Bader 1996 reports a garden path effect).

Prosodic effect: (c) involves a stress clash and should be more difficult than (d) → implicit stress shift/ stress deletion required on the verb. Stress on both “mehr” and on initial syllable of “feststellen” is problematic.

# Experiment I: unprepared reading



5000 ms

# Experiment I: Procedure and data analysis

## Procedure

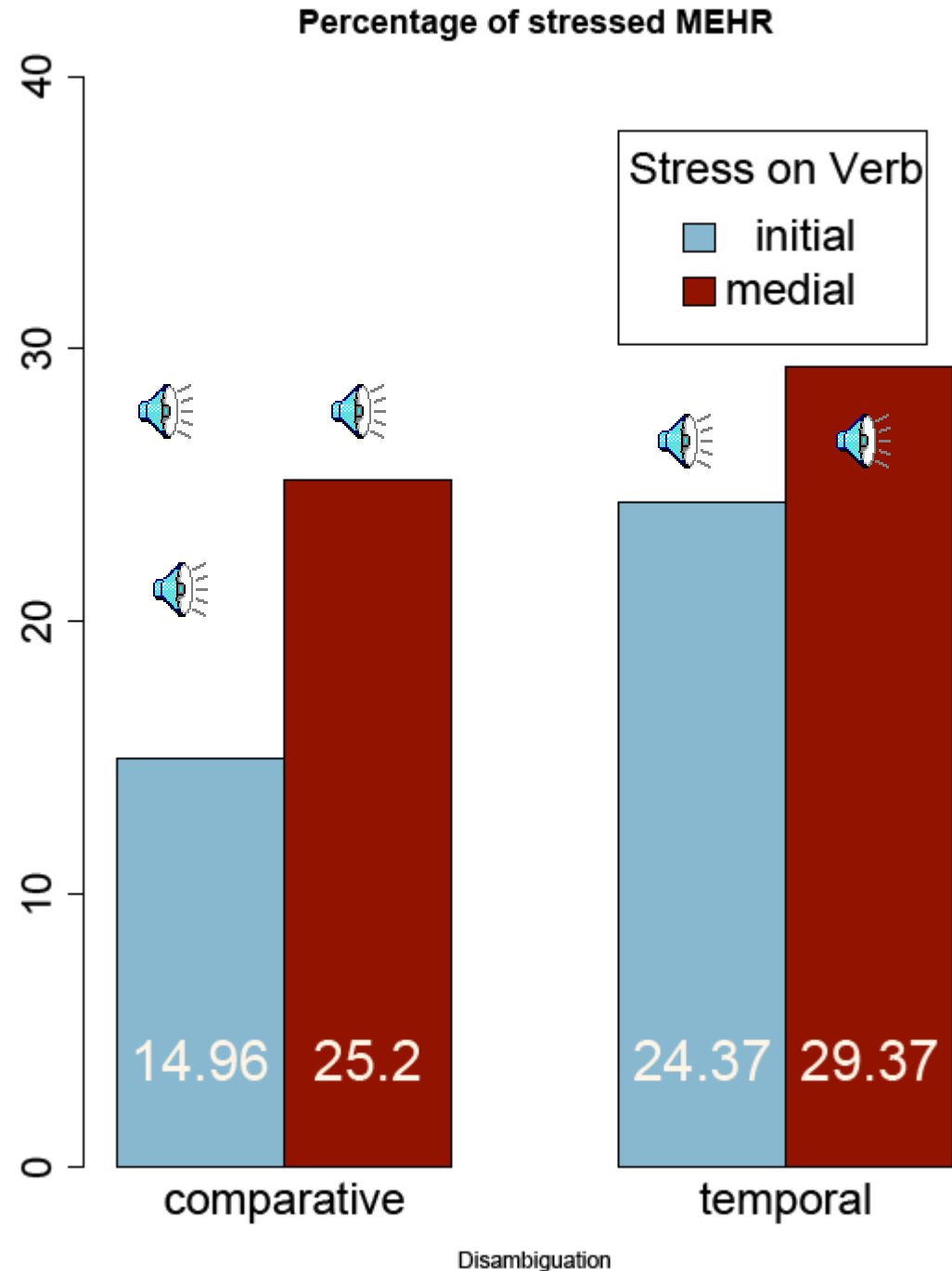
- 24 participants read 24 sentences in 4 conditions from screen without preparation = 576 experimental sentences

## Data analysis

- 63 sentences (11%) discarded because of slips of the tongue or hesitations.
- Other sentences were cut before disambiguating region and judged for stress on „*mehr*“.

# Results

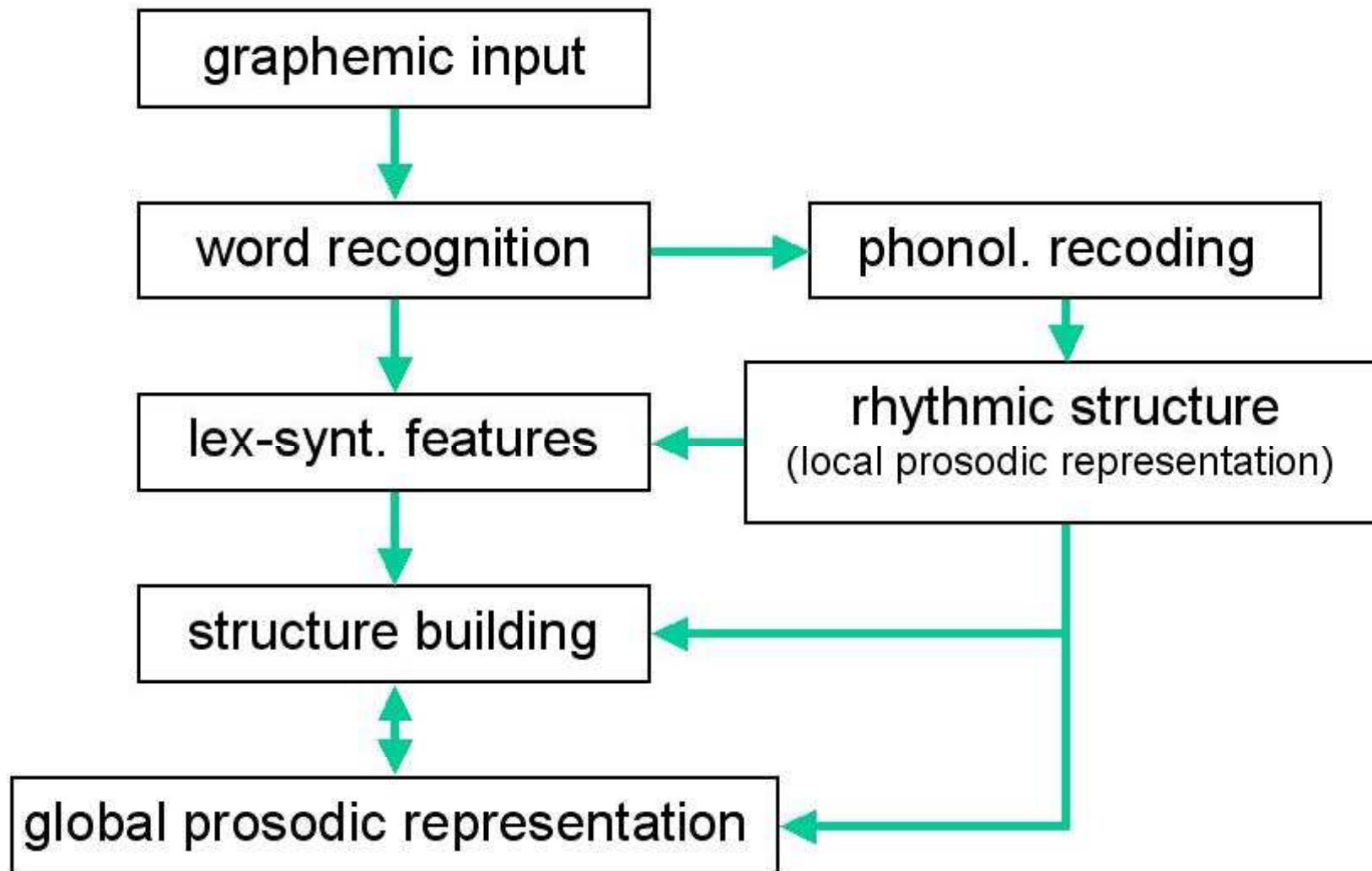
- Across conditions “*mehr*“ was stressed in ~23.5% of cases
- “*Mehr*“ was stressed less often when followed by a verb with initial stress ( $z=-2.61$ ,  $p<0.01$ ).
- “*Mehr*“ was stressed less often in sentences with comparative disambiguation ( $z=-1.977$ ,  $p=0.048$ ).
- Interaction of rhythmic environment and disambiguation non-significant.



# Experiment I: Discussion

- The rhythmic environment directly affects structure building during reading aloud.
- Although stress information is not explicitly encoded in the written string, it has a significant effect on participant's choice of reading.
- Readers avoid renditions that involve a stress clash.
- Readers avoid costly prosodic adjustments in the face of a possible stress clash by adopting a syntactic parse that results in a prosodically inconspicuous representation.
- The parser uses rhythmic information for incremental structure building.

## Extended model for prosody generation in reading



# Motivation for Experiment II

- Experiment I indicates that rhythmic environment to the right of critical word *mehr* influences stress placement on *mehr* (leftward clash resolution).

How about the left environment (rightward resolution)?

Clash resolution in English (leftward shift):

/thirtéen/ /bóyscouts/

thìr[teen bóy]scouts

\*thir[tèen boy]scóuts

In German, rightward shift is possible:

/Gást/ /árbeiter/

[Gástar]bèiter

\*[Gastár]beiter

/den Róck/ /ánziehen/

den [Róck an]ziehen

\*den [Rock án]ziehen

# Experiment II

Testing the effect of rhythmic structure on the realization of contrast in reading aloud.

Rhythmic environment to both left and right of a critical element in contrastive focus were tested:

3 Factors; 2x2x2 Experiment

1. Sentence type: Elliptic vs. Non-elliptic
2. Rhythmic environment to the left: Clash vs. NoClash
3. Rhythmic environment to the right: Clash vs. NoClash

# Experiment II

Testing the effect of rhythmic structure on the realization of contrast in reading aloud.

- In German, contrasted elements are prosodically prominent (contrastive accentuation).
- Example: Elliptic coordinations (RNR):
  1. Hans schläft und Maria verkauft Schallplatten.
  2. Hans sammelt und Maria verkauft Schallplatten.  
*Hans sleeps/collects and Maria sells records*

# Experiment II

1. Der Maurer lächelt und der Admiral isst Kuchen mit Sahne.
2. Der Maurer lächelt und die Lehrerin isst Kuchen mit Sahne.
3. Der Maurer lächelt und der Admiral isst Gebäck mit Sahne.
4. Der Maurer lächelt und die Lehrerin isst Gebäck mit Sahne.

*The bricklayer is smiling and the admiral/teacher is eating cake/cookies*

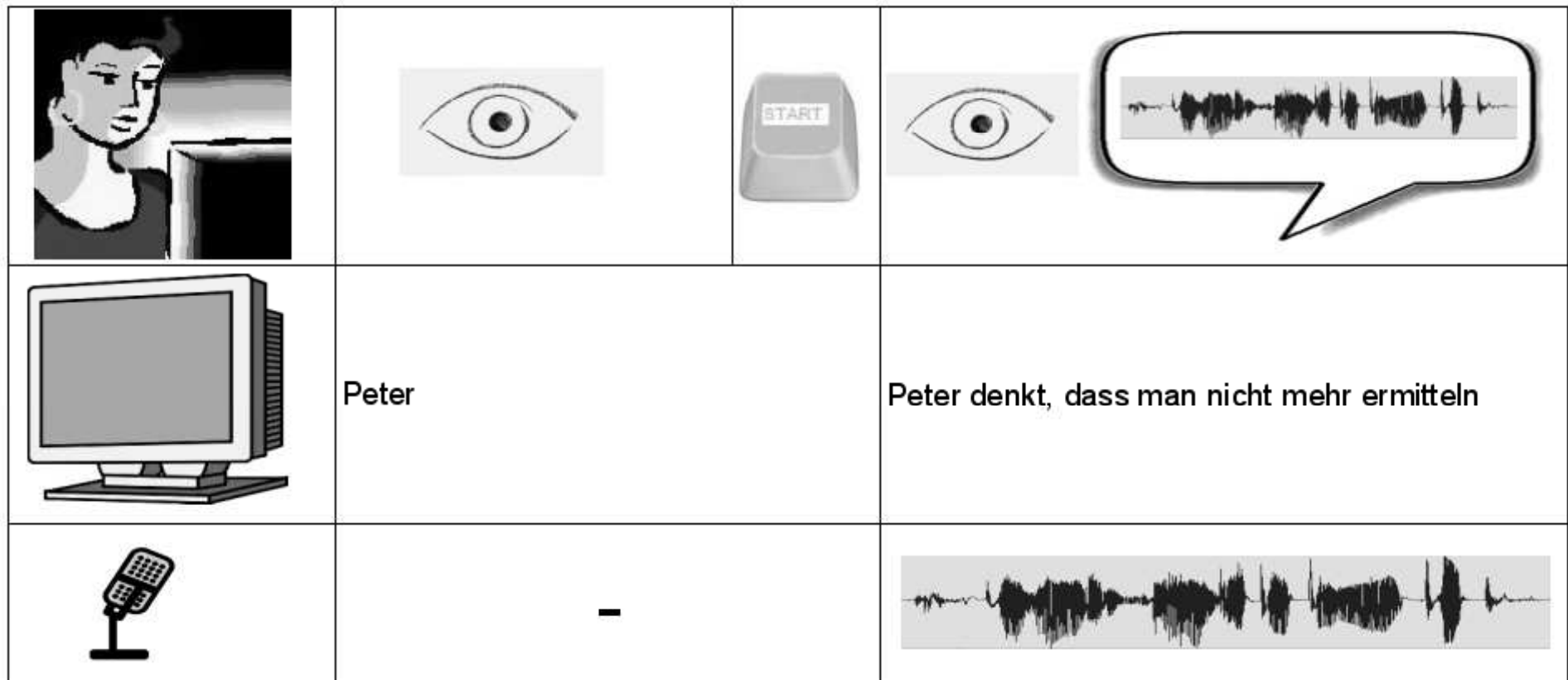
*→ contrastive stress on isst is not licensed !*

5. Der Maurer holt und der Admiral isst Kuchen mit Sahne.
6. Der Maurer holt und die Lehrerin isst Kuchen mit Sahne.
7. Der Maurer holt und der Admiral isst Gebäck mit Sahne.
8. Der Maurer holt und der Lehrerin isst Gebäck mit Sahne.

*The bricklayer is bringing and the admiral/teacher is eating cake/cookies*

*→ contrastive stress on isst is mandatory !*

# Experiment II: unprepared reading



5000 ms

# Experiment II: Procedure and data analysis

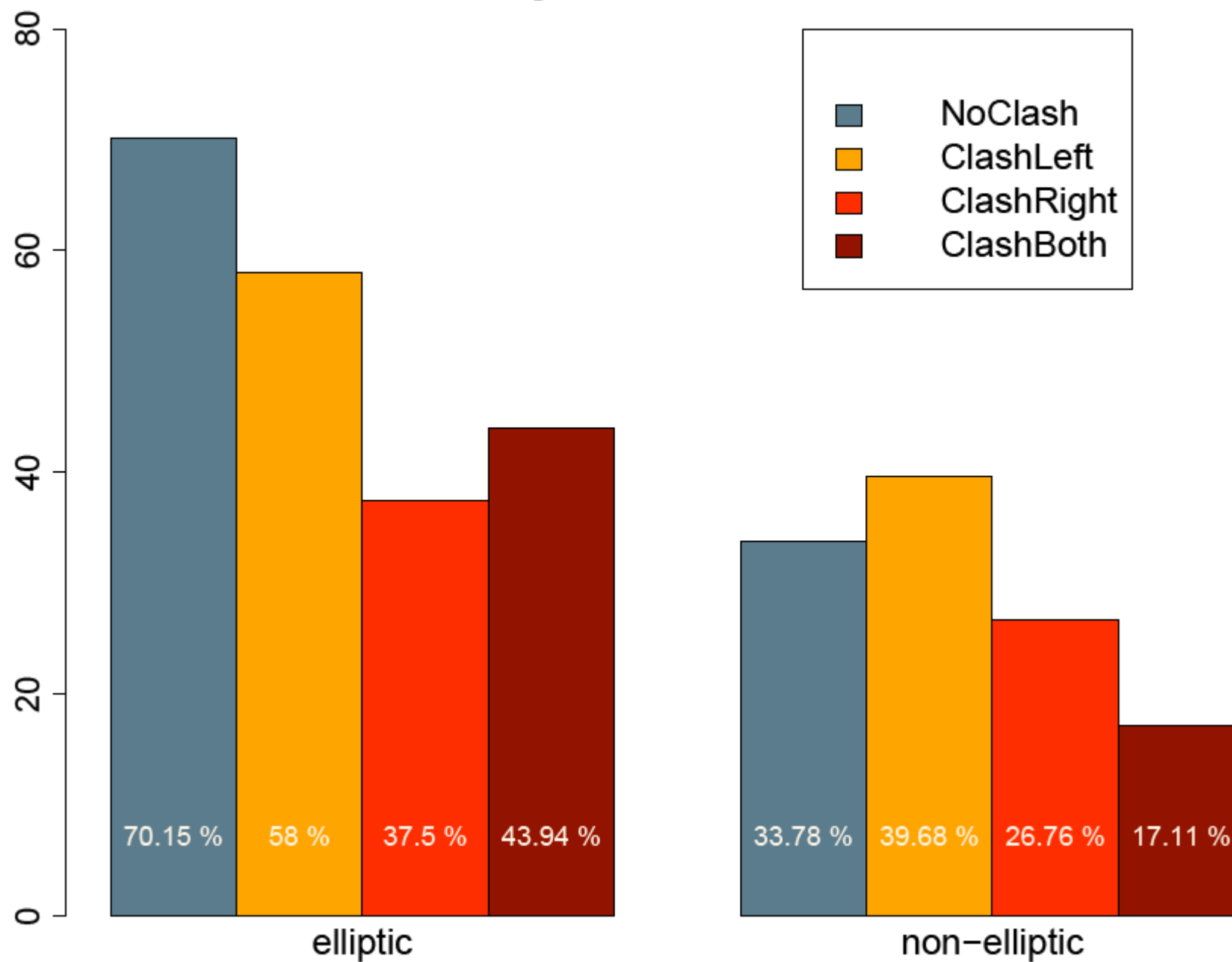
## Procedure

- 24 participants read 28 sentences in 8 conditions from screen without preparation = 672 experimental sentences

## Data analysis

- 109 sentences (16%) discarded because of slips of the tongue or hesitations.
- Sentences were judged for contrastive stress on 2nd verb.

Percentage of contrastive stress on Verb



# Experiment II: Results

Fixed effects:

	Estimate	Std.Error	z-value	Pr(> z )
(Intercept)	-0.48697	0.24943	-1.952	0.0509 .
<b>clashLeft</b>	-0.08526	0.10165	-0.839	0.4016
<b>clashRight</b>	<b>-0.53407</b>	<b>0.10231</b>	<b>-5.220</b>	<b>1.79e-07 ***</b>
<b>reading</b>	<b>0.64172</b>	<b>0.10242</b>	<b>6.266</b>	<b>3.71e-10 ***</b>
clashL:clashR	0.03894	0.15028	0.259	0.7955
clashL:reading	-0.05432	0.10163	-0.534	0.5930
clashR:reading	-0.08636	0.10111	-0.854	0.3931
clashL:clashR:reading	0.08163	0.13048	0.626	0.5315

## Experiment II: Discussion

- The rhythmic environment affects the realization of stress on the critical word in unprepared reading.
- Only the environment to the right shows a significant effect on realization of stress (leftward shift / de-stressing).
- The rhythmic environment overrides syntactic and information structural requirements in this task  
→ speakers realize rhythmically optimal structures at the expense of the grammaticality of their productions.

# General discussion

Unprepared reading aloud involves both sentence comprehension and production. The realizations reflect the readers' incremental analysis of the sentence.

The rhythmic environment affects the realizations of stress on critical words

- Readers prefer rhythmically optimal renditions at the expense of the grammaticality of their productions (shallow processing).
- The parser uses rhythmic information to make syntactic and information structural decisions.
- Asymmetry of rhythmic environment: leftward clash resolution confirmed; no rightward resolution detected.

# Some open questions

- Relation between comprehension and production in reading aloud not entirely clear. Do speakers really produce the result of their syntactic analysis of the written string? → evidence for garden path effects?
- What about implicit prosody in silent reading?
- What is the nature of the asymmetry for stress clash resolution?

Thank you!